IEP-SAC JOURNAL

2024-25

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Riyadh, Kingdom of Suadi Arabia

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IEP-SAC Journal is published yearly by the Institution of Engineers Pakistan, Saudi Arabian Center (IEP-SAC), Riyadh, and distributed to the engineering community in Saudi Arabia. To promote discussion of issues in the field of engineering and ensure coverage of all responsible points of view, conflicting opinions and views may appear, however, IEP-SAC cannot accept any liability for such views nor for any errors or omissions.

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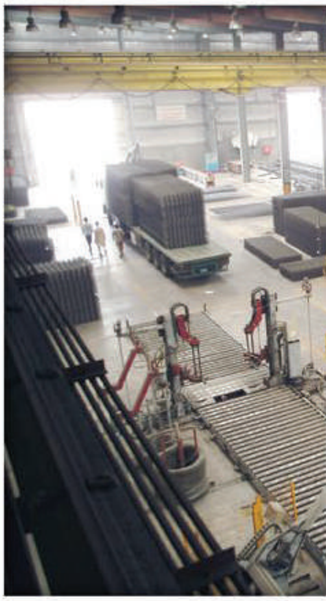
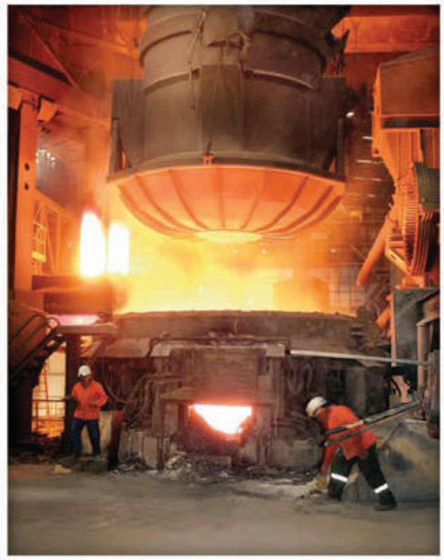
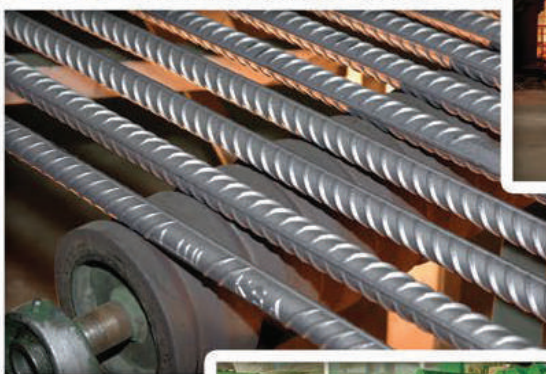

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Message from the Chairman IEP-SAC

Next Generation Construction Technologies

The Institution of Engineers Pakistan-Saudi Arabia Center (IEP-SAC) is a professional platform dedicated to supporting Pakistani engineers in the Kingdom of Saudi Arabia (KSA). Under the patronage of the Embassy of Pakistan, IEP-SAC fosters networking, professional development, and knowledge sharing. Through seminars, technical papers, and social engagements, we help engineers stay updated with the latest advancements in the industry. Additionally, we extend support to deserving engineering students in Pakistan, reinforcing our commitment to the profession.

Currently, we are preparing for our Annual Engineers' Convention, featuring a seminar on "Construction 4.0 and Beyond: Next Generation Construction Technologies", to be delivered by Prof. Dr. Salman Azhar, Graduate Program Chair, School of Building Science, Auburn University, USA. The seminar will explore cutting-edge technologies such as Building Information Modelling (BIM), Digital Twins, Construction Robotics, Reality Capture, 3D Concrete Printing, and Digital Fabrication, highlighting their transformative impact on industry.

I am also pleased to present the IEP-SAC Journal 2024-2025, which compiles technical papers and key activities organized by IEP-SAC to enhance engineering knowledge and professional growth. I encourage all Pakistani engineers to actively participate, become members of IEP-SAC, and contribute to building a better future for your profession.

IEP-SAC extends its heartfelt appreciation to fellow engineers for their dedication, professionalism, and invaluable contributions to Saudi Arabia's development. On behalf of IEP-SAC, I express gratitude to the Custodian of the Two Holy Mosques, King Salman bin Abdul Aziz Al-Saud, and Crown Prince His Royal Highness Muhammad bin Salman bin Abdul Aziz for their unwavering hospitality and support for the Pakistani community and engineers.

We also extend our sincere thanks to H.E. the Ambassador of the Islamic Republic of Pakistan for his continuous patronage of IEP-SAC. Additionally, we acknowledge the generous contributions of our sponsors and fellow engineers, whose support is vital to our success. I extend my sincere appreciation to IEP-SAC Council Members for their dedication and commitment to our shared goals.

Lastly, we express our gratitude to Allah (SWT) for granting IEP-SAC the resources, energy, and opportunities to serve the engineering community. Wishing you all happiness, success, and a prosperous future ahead.

Rafiq M. Choudhry

Prof. Rafiq Muhammad Choudhry, Ph.D., PE, FIE(Pak)

Chairman, IEP-SAC, KSA, Friday 28 March 2025 (28 Ramadan, 1446)

Message from H.E. Ahmad Farooq, Ambassador of Pakistan to the Kingdom of Saudi Arabia

It is a privilege to extend my warmest congratulations to the Institute of Engineers of Pakistan — Saudi Arabia Chapter (IEP-SAC) on the publication of their annual journal. This journal is a testament to the dedication and professionalism of IEP-SAC, which continues to serve as a source of inspiration and guidance for Pakistani engineers and professionals residing in the Kingdom of Saudi Arabia.

The role of Pakistani engineers in the Kingdom's development cannot be overstated. Their technical expertise, innovative mindset, and commitment to excellence have not only contributed significantly to Saudi Arabia's progress but have also strengthened the enduring bond between our two nations. These professionals are a source of pride for Pakistan, exemplifying the values of hard work, integrity, and innovation. Their achievements pave the way for future generations, ensuring that Pakistan's legacy of excellence continues to thrive in Saudi Arabia.

I would also like to take this opportunity to commend IEP-SAC for its commendable efforts in fostering community welfare and supporting education through scholarships for deserving students in Pakistan. Such initiatives reflect the organization's commitment to uplifting society and empowering individuals through knowledge and opportunity. This spirit of giving and solidarity is a hallmark of our culture and a beacon for others to follow.

The Embassy of Pakistan remains dedicated to supporting initiatives that promote the well-being and advancement of our community in Saudi Arabia. We view IEP-SAC as a valuable partner in this mission and are committed to facilitating all its endeavours that are aimed at strengthening professional ties, fostering goodwill, and enhancing Pakistan's image in the Kingdom.

As you embark on another year of impactful work, I wish IEP-SAC continued success in all its initiatives. May this journal serve as a source of inspiration and knowledge for all its readers, furthering the professional growth and unity of our community.

Ahmad Farooq

Ahmad Farooq

Ambassador

Embassy of the Islamic Republic of Pakistan
Riyadh, Kingdom of Saudi Arabia


KELLER

Message From
Engr. Farhat Adil FIE (PAK)
President

INSTITUTION OF ENGINEERS PAKISTAN

It is with great pleasure that I congratulate the Institution of Engineers, Pakistan – Saudi Arabia Centre(IEP-SAC), an overseas centre of the IEP, for organizing the Annual Technical Seminar in Riyadh.

The significance of this event lies in the fact that eminent expert engineers are presenting their-valuable technical papers. The technical and social activities organized by the Centre over the years will also be highlighted, contributing to the enhancement of engineering knowledge and the profession.

On behalf of the Central Council of the Institution of Engineers, Pakistan (IEP), and my own behalf, I wholeheartedly congratulate the office bearers of IEP-SAC, as well as the members of the standing committees, for organizing this seminar, publishing the engineering journal, and awarding scholarships to engineering students on a need and merit basis. This journal contains important articles on current engineering issues, and its launch during the technical seminar always facilitates the exchange of knowledge and information for the benefit of engineers.

It is also with great satisfaction that I acknowledge IEP local centres, including IEP-SAC, for regularly organizing seminars, national and international engineering conferences, and events such as World Engineering Day, all in line with the vision of the Founder of Pakistan, Quaid-e-Azam Muhammad Ali Jinnah, who stated:

"If Pakistan is to take its proper place among the progressive nations of the world, it will have to take up a good deal of leeway in the realm of scientific and technical education."

Engineers, regardless of whether they are from developed or developing countries, play a vital role in the prosperity of their nations. This is especially true for overseas Pakistani engineers, who contribute by earning foreign exchange and transferring the latest engineering technologies to Pakistan. All nations rely increasingly on engineers who strive to remain at the forefront of economic growth and to navigate the challenges of global economic competition. Engineers have an indispensable role in improving manufacturing processes, and developing efficient communication technologies,transportation infrastructure, and strategic defense systems.

Once again, I congratulate the office bearers of IEP-SAC and the organizers of the seminar, and Iwish them a very happy and prosperous future ahead.

Engr. Farhat Adil FIE (PAK)

President,
The Institution of Engineers, Pakistan

Message From The Secretary General Of

INSTITUTION OF ENGINEERS PAKISTAN

It is both an honor and a pleasure for me to congratulate the Institution of Engineers, Pakistan – Saudi Arabia, IEP Overseas Centre (IEP-SAC), for hosting the Annual Technical Seminar in Riyadh, continuing the tradition of past events. The most significant aspect of this occasion is the publication of the Technical Annual Journal, which features research-oriented technical papers aimed at benefiting the engineering community and the profession, as well as addressing current engineering issues. The importance of this event is highlighted by the participation of eminent engineers from various disciplines, who are presenting their valuable technical papers.

It is also with great satisfaction that IEP-SAC Overseas Centre successfully organized the 65th and 66th IEP-SAC Technical Seminars. During these events, distinguished engineers such as Engr. Khawar, who presented his paper on “Precision Gears for Stateof-the-Art Machines,” and Engr. Prof. Dr. Salman Azhar, who presented “Construction 4.0 and Beyond: Next Generation Construction Technologies,” aligned their presentations with UNESCO’s goals for Sustainable Development.

I am proud to say that engineers from every country, whether developed or developing, play a vital role in the prosperity of their nations. All nations rely on engineers to maintain their competitive edge in a rapidly evolving global economic landscape. Engineers are essential in advancing manufacturing processes, developing efficient communication technologies, transportation infrastructure, and strategic defense systems. I would also like to congratulate the Chairman, all Vice Chairmen, the Secretary, and the Local Council Members of IEP-SAC for successfully organizing the Annual Seminar and publishing the Technical Annual Journal. I wish continued success for the seminar and its future endeavors.

Engr. Amir Zamir Ahmed Khan

Secretary General,
The Institution of Engineers, Pakistan

IEPSAC CENTRAL REGION

ANNUAL REPORT FOR 2024-25

الحمد لله رب العالمين، والصلاة والسلام على سيد الأنبياء والمرسلين، نبينا محمد، وعلى آله وصحبه أجمعين

As we turn the page on another remarkable year, the Institution of Engineers Pakistan – Saudi Arabian Center (IEP-SAC) proudly presents this report, reflecting a journey of progress, collaboration, and continued dedication to professional excellence.

From impactful seminars on sustainability and precision engineering to engaging community events and council developments, each milestone demonstrates the strength and commitment of our organization. We have remained focused on professional excellence, learning, growth and collaboration throughout the year.

IEP-SAC has always thrived through change. While people come and go, the organization moves forward; energized by the fresh ideas and commitment of new members. Every fresh perspective fuels our growth and drives our purpose.

This report captures the highlights of 2024-25 and celebrates the collective efforts that have shaped another successful chapter for IEP-SAC.

Let us now revisit the moments that made this year truly memorable.

64th IEP-SAC TECHNICAL SEMINAR – May 24, 2024

The 64th Technical Seminar of the Institution of Engineers, Saudi Arabian Center (IEP-SAC) was successfully held on Friday, May 24, 2024, at the Embassy of Pakistan, Riyadh, KSA. This year's keynote speaker was Engr. Muhammad Asim Baig, who delivered an insightful presentation on 'Sustainability - Advanced Concepts, Opportunities, and Solutions.' His talk explored cutting-edge sustainability practices, innovative solutions, and the growing global emphasis on sustainable development.

The seminar delved into advanced sustainability concepts such as stakeholder engagement, gap analysis, risk assessment, and strategic sustainability planning. It highlighted smart solutions including renewable energy, energy efficiency, sustainable transportation, sustainable agriculture, circular economy, green buildings, water conservation, and community engagement. Participants also gained insights into the 6Ps and 5Rs of sustainability, the 17 UN Sustainable Development Goals (SDGs) and their global impact scores, as well as sustainability initiatives under Vision 2030. Additionally, international sustainability certifications such as ISO 14001, LEED, ASI, and MOSTADAM were explored, providing valuable insights into global best practices.

The seminar commenced with a recitation from the Holy Quran by Engr. Dr. Hafiz Muhammad Imran. Registration at the venue took place between 7:30-8:00 PM. The esteemed Chief Guest, H.E. Ahmad Farooq, Ambassador of Pakistan, graced the event with his presence. Engr. Mian Abdul Hamid, the technical committee convener, introduced the speaker and led an engaging Q&A session. Engr. Asim Siddiqui, General Secretary, IEP-SAC, provided an overview of the center's activities, while Engr. Abdul Qadir Akbani presented an update on the eastern regional activities. Additionally, Engr. Farooq Iqbal, Convener Scholarships Committee, shared the latest developments in scholarship initiatives, reinforcing our commitment to supporting engineering students in Pakistan.

Before the event concluded, certificates were awarded to contributors of research publications featured in the IEP-SAC Journal. The Chief Guest honored the keynote speaker with an honorary shield, while the Chairman IEP-SAC, Engr. Prof. Dr. Rafiq Muhammad Choudhry, presented a commemorative token to the Chief Guest. The event concluded with a group photograph and a networking dinner.

Mid-Term Seminar – December 6, 2024

The Institution of Engineers Pakistan Saudi Arabian Centre (IEP-SAC) arranged a Mid-Term Seminar on December 6, 2024, on the topic of "PRECISION GEARS FOR STATE-OF-THE-ART MACHINES." The keynote speaker was Engr. Muhammad Khawar Anwar, Owner and Founder, All American Gears and Components, Inc., Farmingdale, New York, USA. The Chief Guest of the event was Rana Muhammad Masoom, the Welfare Attaché of the Embassy of Pakistan in Saudi Arabia.

Engr. Khawar took the attendees on an insightful journey through Gear Engineering, from historical perspectives to modern-day Precision Gear Designing and Manufacturing. He elaborated on the critical role of fine-pitch precision gears, their design, manufacturing, and their significance in various engineering applications. He emphasized that gears are an essential component of any machine, playing a crucial role in power transmission, speed control, motion direction, and torque adjustment.

With the advent of intelligent and smart systems, gear mechanisms must now function smoothly and efficiently within much tighter limits, presenting a significant challenge for both gear designers and manufacturers. Engr. Khawar highlighted the evolution of fine-pitch precision gear designing and manufacturing as a cutting-edge field requiring precise tolerances and specialized gear-cutting tools.

The Chief Guest appreciated IEP-SAC's efforts in organizing professional development events and commended the organization's scholarship program, which supports underprivileged engineering students in various Pakistani universities.

The seminar concluded with a shield presentation ceremony, where Engr. Dr. Rafiq Muhammad Choudhry, Chairman IEP-SAC, presented shields to both the Chief Guest and the keynote speaker. He extended his gratitude to all participants for their attendance and contributions to the event's success.

Annual Family Picnic – January 24, 2025

The much-anticipated annual family picnic took place on January 24, 2025, at Muzahimiyah, providing a day filled with entertainment, camaraderie, and relaxation. This full day gathering included various activities such as cricket, football, tug-of-war, table tennis, carrom board, and children's competitions, ensuring a memorable experience for all attendees.

The Chairman IEP-SAC, Engr. Dr. Rafiq Muhammad Choudhry, extended his heartfelt thanks to the participants and the organizing committee for their dedication. The event culminated in a prize distribution ceremony, where winners of various competitions were recognized. Engr. Riaz Ahmad, Convener of the event committee, conducted the ceremony and expressed gratitude to all sponsors for their invaluable support.

Changes in the Local Council

One of the senior members of the council, the Ex-Chairman of IEP-SAC, Engr. Syed Muhammad Iqbal, left the country in September 2024. The council organized a farewell dinner in his honor and appreciated his exceptional services for the Pakistani engineering community in Saudi Arabia.

During the year, the following new members joined the Central Region Council:

Engr. Dr Babar Azeem

Engr. Fahim Uddin

Engr. Bilal Yousaf

Engr. Masood Ul Hassan

Engr. Syed Mujtaba Omer Junaidy

Engr. Wasil Hussain Syed

Engr. Salman Rashid

Looking Ahead

As we bring this report to a close, we extend our sincere thanks to the council members, partners, and supporters whose dedication has shaped the success of IEP-SAC in this past year. Your passion and commitment remain the cornerstone of our progress.

We also express our deep gratitude to the Custodian of the Two Holy Mosques, King Salman Bin Abdul Aziz, and His Royal Highness, Prince Mohammad Bin Salman Bin Abdul Aziz, for their unwavering support of the Pakistani community in Saudi Arabia. Their vision and leadership continue to inspire us in our journey.

Looking ahead, we remain committed to excellence, innovation, and unity. May the year ahead bring new milestones and strengthened bonds within our engineering fraternity.

Warm regards,

Mohammad Asim Siddiqui

Secretary, IEP-SAC Central Region

IEP-SAC AWARDS AND SCHOLARSHIPS COMMITTEE

لَيْسَ الْبِرَّ اَنْ تُوَلُّوْا وُجُوْهَكُمْ قِبَلَ الْمَشْرِقِ وَالْمَغْرِبِ وَلٰكِنَّ الْبِرَّ مَنْ اٰمَنَ بِاللّٰهِ وَالْيَوْمِ الْاٰخِرِ وَالْمَلٰٓئِكَةِ وَالْكِتٰبِ وَ
النَّبِيّٖنَ ۚ وَاٰتَى الْمَالَ عَلٰى حُبِّهٖ ذَوِى الْقُرْبٰى وَالْيَتٰمٰى وَالْمَسٰكِيْنَ وَابْنَ السَّبِيْلِ ۙ وَالسَّآئِلِيْنَ وَفِى الرِّقَابِ ۚ .... ﴿۱۷۷﴾

اِنْ تُبْدُوا الصَّدَقٰتِ فَنِعِمَّا هِىَ ۚ وَاِنْ تُخْفُوْهَا وَتُؤْتُوْهَا الْفُقَرَآءَ فَهُوَ خَيْرٌ لَّكُمْ ۭ وَيُكَفِّرُ عَنْكُمْ مِّنْ سَيِّاٰتِكُمْ ۭ وَاللّٰهُ
بِمَا تَعْمَلُوْنَ خَبِيْرٌ ﴿۲۷۱﴾

"But Al-Birr (righteousness, piety) is the quality of one who believes in Allah, and the Last Day, and the Angels, and the Book, and the Prophets and distributes his wealth, in spite of love for it, to the kinsfolk, and to the orphans, and to the needy, and to the wayfarer, and to those who ask, and to the ransom of prisoners." (Al-Baqarah-177)

"If you disclose your (acts of) charity, it is well, but if you conceal it, and give it those (really) in need, that is better for you; it will remove from you some of your (stains of) sins and Allah is well acquainted with what you do." (Al-Baqarah-271)

The Engineer plays an important role in the development of any country and build a better world. IEP-SAC, Saudi Arabian chapter of The Institute of Engineers Pakistan under the patronage of the Embassy of Islamic Republic of Pakistan in Saudi Arabia along with other technical and social activities is also playing its role in supporting Engineering education in Pakistan.

By the grace of Allah the Almighty, the IEP-SAC scholarship program for needy and academically sound students in the Engineering Universities and Colleges of Pakistan was launched 28 years ago in the year 1996. With the joint efforts of IEP-SAC, Local Council members, and others, it has been expanding ever since and presently 96 students from the below listed 12 public-sector universities and colleges are benefiting from this program.

1. University of Engineering and Technology, Lahore
2. University of Engineering and Technology, Taxila
3. University College of Engineering and Technology (Bahauddin Zakariya University), Multan
4. Institute of Chemical Engineering and Technology (University of the Punjab), Lahore
5. Dawood University of Engineering and Technology, Karachi
6. NED University of Engineering and Technology, Karachi
7. Mehran University of Engineering and Technology, Jamshoro
8. Quaid-e-Awam University of Engineering Sciences and Technology, Nawabshah

9. NWFP University of Engineering and Technology, Peshawar

10. Baluchistan University of Engineering and Technology, Khuzdar

11. Mirpur University of Science and Technology, Mirpur (AJ&K)

12. Khawaja Fareed University of Engineering and Information Technology, Rahim Yar Khan

As can be noted from the list, this scholarship program serves all the four provinces of the Islamic Republic of Pakistan and the State of Azad Jammu and Kashmir. The rules and regulations, selection criteria and application forms can be accessed and printed from IEPSAC website. By the blessings of Allah the Almighty, 25 batches of the scholarships have been completed so far and 26th batch was launched in January 2025, benefiting meritorious and needy students from this scholarship program who will serve the humanity and our homeland after graduation.

The continuity of IEP-SAC scholarship program has not only been maintained during last 28 years, but it has also been expanding gradually with the help of financial contributions from various philanthropists, individuals, and organizations in Saudi Arabia. I take the opportunity to offer the readers of these lines in general and the Pakistani community and engineers in particular to join hands with us in this noble and just cause. It is a great service to the Engineering community in Pakistan. It is my humble request to all to put our maximum efforts in contributing and expanding the scholarship program to the needy and deserving engineering students in Pakistan.

Your suggestions to improve this noble cause further will be most welcomed. Please do not hesitate to contact any of the members of IEP-SAC Awards and Scholarships Committee or Local Council for any suggestion or information.

Arch. Farooq Iqbal, Convener

IEP-SAC Awards and Scholarships Committee

IEP–SAC LOCAL COUNCIL

Central Region 2024-25

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2024-25

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SCENES FROM IEP–SAC Activities

CENTRAL REGION

Annual Seminar 24 May 2024

SCENES FROM IEP-SAC Activities

CENTRAL REGION

Annual Seminar 24 May 2024












SCENES FROM IEP-SAC **Activities**

CENTRAL REGION

Annual Family Picnic 24 January 2025











SCENES FROM IEP-SAC Activities

CENTRAL REGION

Annual Family Picnic 24 January 2025












SCENES FROM IEP-SAC Activities

CENTRAL REGION

Midterm Seminar 6th Dec-2024










IEP-SAC Organization and Standing Committees
Riyadh, Saudi Arabia, 2025

Organization	
Name of local council member	**Role**
Engr. Prof. Dr. Rafiq Muhammad Choudhary	Chairman
Engr. Mian Abdul Hamid	Vice Chairman
Engr. Muhammad Asim Siddiqi	Secretary

Advisors	
Engr. S. M. H. Kirmani	Ex-Chairman IEP-SAC
Engr. Syed Jaleel Hassan	Ex-Chairman IEP-SAC

Technical Seminar Committee	
Name of LC member	**Role**
Engr. Dr. Fakhir Hasani	Convener
Engr. Dr. Babar Azeem	Co-Convener
Engr. Dr. Hafiz Muhammad Imran	Member
Engr. Waqar Ahmad Malik	Member

Scholarships Committee	
Name of LC member	**Role**
Arch. Farooq Iqbal	Convener
Engr. Wasil Hussain Syed	Co-Convener
Engr. Dr. Fakhir Hasani	Member
Engr. Ijaz Akhtar	Member

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Message from Chairman IEP -SAC
(Eastern Region)

On Behalf of IEP–SAC, Eastern Region, I am delighted to report the activities and the events that IEP-SAC-EP has organized during 2024/2025.

The acquisition of Knowledge is a prime obligation for all human beings. The Holy Quran emphasis to read, write, research and explore the universe to see the signs of the Almighty.

Vision is the power of imagination to foresee and analyze resources. Vision allows us to shape up the future for the benefit of the nation.

Quaid-e-Azam was a visionary leader, founder of a great nation, emphasized on sharing engineering knowledge.

Since the founding of overseas chapter of the institution of Engineers Pakistan in Saudi Arabia (IEP-SAC) in 1989, we have been following the footsteps of the IEP as Quaid-e-Azam M. Ali Jinnah founded it in 1948.

Engineers keep on researching, developing and upgrading their knowledge to construct and reconstruct human needs with a view improving the living conditions of the mankind. Sharing information about new technologies for multifaceted engineering activities, networking and assisting engineering graduates for their career development is a passion of IEP-SAC-EP.

We have a very dedicated team of engineers who go above & beyond what is required.

Technical seminars, awarding scholarships to competent engineering students in need and assisting fresh graduates to place them in the industry and guiding other engineers for their respective needs is the continued mission of IEP-SAC-EP.

In October 2024, local council of IEP-SAC-EP entrusted me with the responsibility of being the chairman of Eastern Province for the biennial term of 2024-2026. The other two office bearers endorsed by the local council are Engr. Mohammad Abrar Shami as Vice Chairman and Engr. Nabeel Pervaiz Malik as General Secretary. Four conveners of the IEP-EP standing committees were revamped whereas the other three past conveners were requested to continue their responsibilities with the same committees. The past chairmen Engr. Ismat Amin Khawaja and Engr. Rizwan Ahmed were requested to play their active role as advisors in the committee for the benefit of the engineers and they accepted the request of the new chairman.

By the grace of Almighty Allah, we have continued pursuing our objective, techno-social activities, meetings and sharing creative and innovative technical knowledge among all disciplines of engineering on multi-national ground during 2024-2025.

IEP-EP is proud of organizing a high-profile seminar on De-carbonization, presented by Engr. Muhammad Aijaz Umer on May 28-2024.

Engr. Muhammad Aijaz Umer is a graduate mechanical engineer from NED University of Engineering and technology. He is presently working as executive vice president in ACWA Power. He is an experienced power industry expert.

1. The Topic was **Decarbonization: Current Status and Future Technology Pathway**. The conventional fossil-fuel powered electric generation contributes significantly to global carbon dioxide (Co2) emissions, resulting in detrimental environmental impacts & global warning. He explained that Gas turbines are now utilizing 50 % green hydrogen in the gas mix. It is anticipated that these turbines will generate with 100 % green hydrogen by the year 2030.

   Engr. Abdul Aziz Al-Sultan, VP of Saudi Electric company graced the occasion as the Chief Guest at Mercure Hotel Al-Khobar. The seminar was attended by a large number of engineers and executives of various nationalities as well as researchers from academia.

2. A webinar was organized on Dec 10 -2024, presented by Dr. Imran Khan & Dr. Muhammad Farooq. The topic was "**Industry 4.0 and sustainability Nexus: Pathway to sustainable manufacturing".**

   Strategic approach to adopt the 4.0 industrial revolution driven mainly by Advance digital technologies such as AI, Industrial (IIoT), Block Chain and advances robotics. Speaker elaborated that how these technologies can drive positive environmental, economic and social outcomes.

3. Yet another webinar was organized on Feb 16-2025, presented by Dr.Fahd Saghair and the topic was "**Powering Industrial Evolution: How Digital Innovation is Reshaping Industry"**

   The evolution of Al and digital technologies is transforming industrial operations, enhancing manufacturing automation and efficiency. Speaker talked about the ethical concerns like algorithmic bias, cybersecurity risk and job replacement also require careful consideration. The talk included how to overcome these barriers, ensuring a sustainable and equitable industrial Al transformation.

Life begets life. Energy creates energy. Efforts of Our dedicated team energize the life to gain sustainable and successful performance to provide a meaningful platform to all engineers.

IEP-SAC-EP Executive Council is totally committed and believe that " We can do noble acts without ruling earth & sea" (Aristotle – Greek Philosopher 382-322 BC)

IEP-SAC-EP is pleased to express its gratitude to the Kingdom of Saudi Arabia for its continued hospitality to the Pakistani engineering community. We appreciate and thank our valued sponsors for helping us progress towards our goals. IEP-SAC-EP Council members deserve special mention for their dedicated volunteer work carried out tirelessly with enthusiasm and commitment without which our widespread activities would not have been organized so successful as they were. I thank them all.

Engr. Abdul Qadir Akbani

Chairman. IEP-SAC-EP, KSA

IEP–SAC

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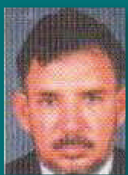

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SCENES FROM IEP–SAC Activities

EASTERN REGION

EP-Annual Seminar 28th May 2024











SCENES FROM IEP–SAC Activities

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SCENES FROM IEP–SAC Activities

EASTERN REGION

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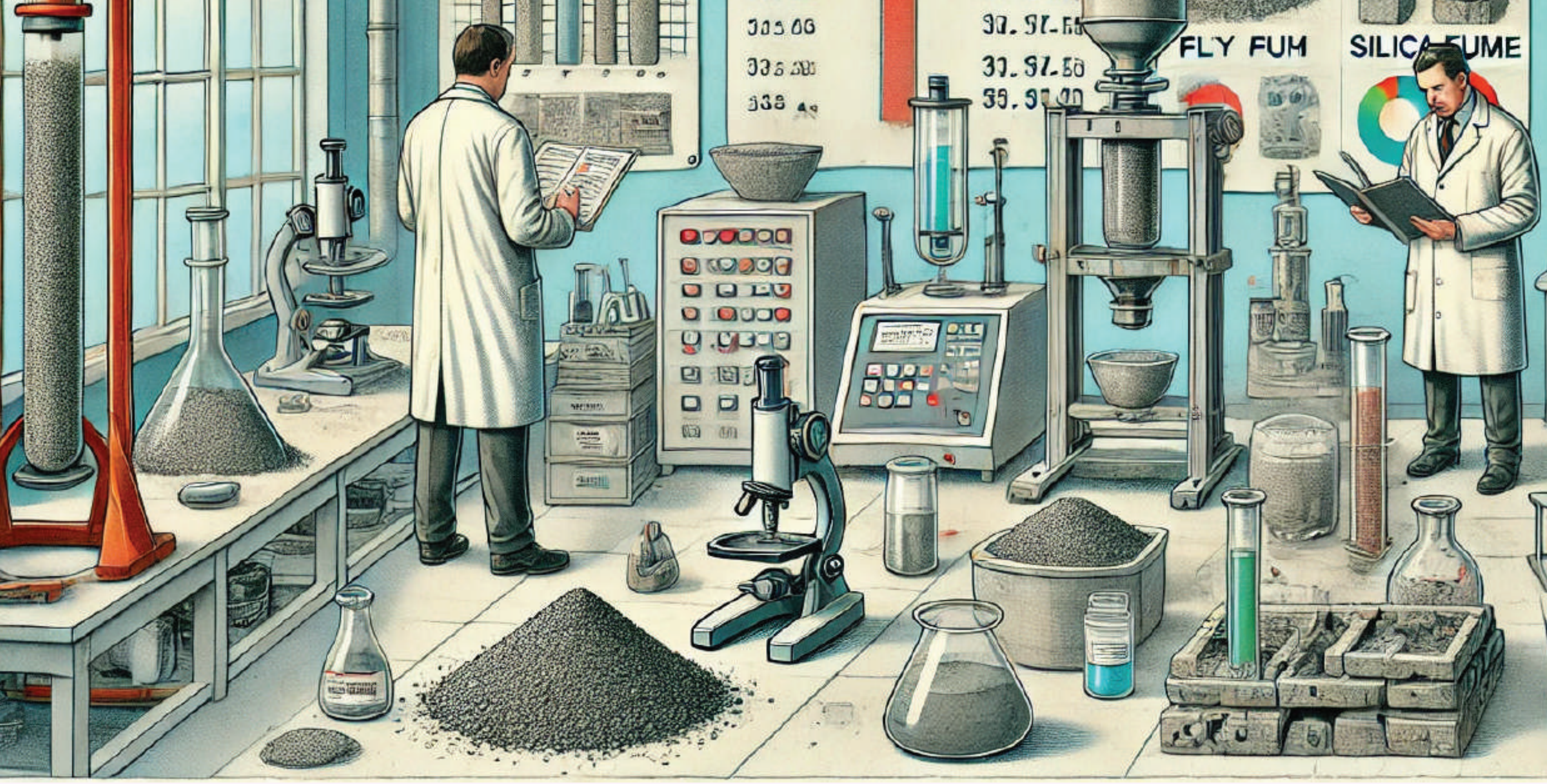


Performance Evaluation of Cement Grouts Using Industrial By-Products for Semi-Flexible Pavements

By: **Dr. Muhammad Imran Khan, and Prof. Rafiq Muhammad Choudhry**

Abstract. Semi-flexible pavement (SFP), a hybrid pavement system that combines open-graded asphalt with cementitious grout, offers enhanced durability, load-bearing capacity, and resistance to rutting compared to conventional pavement systems. Nonetheless, the environmental impact of cement usage in grout formulations remains a significant concern due to its high carbon footprint. This study explores the feasibility of partially replacing ordinary Portland cement with industrial by-products—fly ash (FA) and silica fume (SF)—in cement grouts for SFP applications. Grout mixtures with 5% and 10% replacements of FA and SF were prepared and evaluated for flowability, compressive strength (at 1, 7, and 28 days), and flexural strength (at 28 days). The results demonstrate that FA improves flowability and long-term compressive strength, with a 10% FA replacement achieving a 16% increase in 28-day compressive strength. In contrast, SF enhances early and overall compressive strength but reduces flowability at higher concentrations. Both materials significantly improve flexural strength, with a 5% FA replacement showing a 28% increase over the target value. Based on acceptable flow values and target compressive strength, 10% FA and 5% SF were identified as optimal replacements for cement, achieving a flow

value of 11–16 seconds and a target compressive strength of 60 MPa. These findings highlight the potential of FA and SF as sustainable alternatives to cement, reducing environmental impact while maintaining or enhancing grout performance for SFP applications.

Keywords: semi-flexible pavement, cement grouts, fly ash, silica fume

Introduction

Semi-flexible pavement (SFP), often referred to as Grouted Macadam, is increasingly recognized for its distinctive composition. This innovative material combines an open-graded asphalt mixture with specialized grouting materials [1]. The process involves cement grouts hardening and interlocking with the asphalt mastic, which is made up of fine aggregates, filler, and binder. This fusion creates a unified structure known as SFP, significantly boosting its ability to withstand heavy loads, resist rutting, and prevent deformation under pressure [2]. Designed to deliver enhanced durability, superior load-bearing capacity, and resistance to rutting while retaining a degree of flexibility, SFP has emerged as a promising hybrid pavement solution [3-5].

SFP is characterized by its use of cementitious grout materials that fill a substantial portion (typically 25% to 35%) of the air voids in porous asphalt [5-7]. When compared to traditional concrete and flexible pavements, SFP stands out for its exceptional resistance to rutting and long-lasting durability. It is increasingly viewed as a practical alternative that overcomes the shortcomings of both rigid and flexible pavement systems [8]. Research by Koting et al. highlights SFP's impressive performance in areas such as fatigue resistance, oil spill resilience, and minimizing permanent deformation [9].

The concrete industry's environmental impact is heavily influenced by its high cement consumption. Cement production is a major contributor to industrial emissions, with the process being a significant source of CO2 emissions [10]. To address this issue, researchers have explored the potential of using supplementary cementing materials (SCM) as a partial substitute for cement in concrete mixtures, aiming to promote sustainable construction and reduce environmental harm. Studies have demonstrated that incorporating SCM into concrete can enhance its durability, improve resistance to chloride and acid attacks, and lower permeability. Various types of SCM, such as fly ash, bentonite, straw ash, rice husk ash, palm ash, coconut ash, and sugarcane bagasse ash, silica fume have been identified as viable options for this purpose, each offering unique properties and advantages for construction applications [10-13].

Nevertheless, the dependence on Portland cement in grout formulations poses significant environmental challenges due to its contribution to greenhouse gas emissions. To mitigate these issues, researchers are investigating the potential of utilizing waste materials or industrial by-products as alternatives to cement in grout mixtures for semi-flexible pavement applications. Limited study is available on investigating fly ash and silica fume in cement grouts for semi-flexible pavement application. In line with this objective, the present study investigates the feasibility of partially replacing Portland cement with fly ash (FA) and silica fume (SF), both of which are industrial by-products. Cement grouts were prepared and assessed through flow tests, compressive strength tests (at 1, 7, and 28 days of curing), and flexural strength tests. This approach seeks to reduce both costs and environmental impact while preserving the material's performance characteristics.

Materials and Methods

In this study, fly ash and silica fume were used as a partial replacement of ordinary Portland cement for the preparation of cement grouts for grouted macadam pavements. w/c ratio of 0.35 and dose of superplasticizers of 1% were kept constants for all grouts and were determined. Cement was replaced with 5 and 10 % fly ash and silica fume.

The grouts were mixed and prepared according to ASTM C305 [14].

After preparing cement grouts, flow test on fresh grout were performed using flow cone apparatus in accordance with ASTM C-939. According to literature, the flow out time of grout from the flow cone shall be in the range of 11 to 16 sec. In this test, 1,750 ml fresh grout was poured into the flow cone with closed valve at bottom. Soon after poring, the valve was opened and time taken to empty the flow cone was recorded by stopwatch.

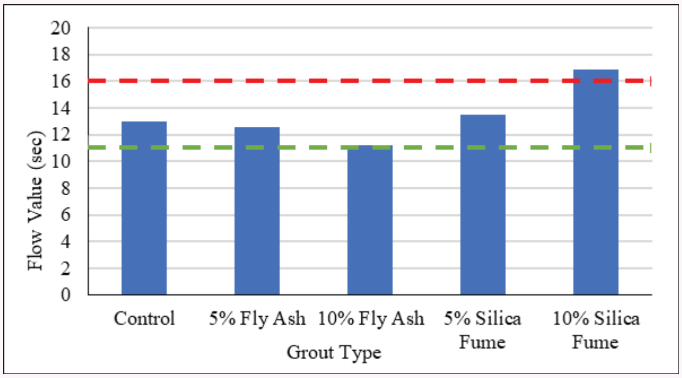
In addition to flow test, the cubes of size 50 mm were filled from cement grouts and kept for 24 hours and were then demolded. After that the cubes were placed in water for curing until test date. After curing the cubes were subjected to compressive test to determine the compressive strength at 1d, 7d and 28 days curing ages. Beam specimens of size (need to write the size) were also prepared and tested for flexural strength test at 28d curing.

3 Results and discussions

3.1 Flow value of grouts

The flow value of cement grouts incorporating fly ash (FA) and silica fume (SF) is presented in Figure 1, with the acceptable range defined as 11 to 16 seconds. The control grout exhibits a flow value of approximately 12.5 seconds, which remains within the acceptable range. The inclusion of 5% FA results in a flow value similar to the control, while increasing FA to 10% reduces the flow to around 11 seconds, marking a decrease of approximately 12% compared to the control. Conversely, adding 5% SF increases the flow value to about 13 seconds (4% higher than the control), whereas 10% SF significantly increases the flow to around 16.5 seconds, exceeding the upper acceptable limit by 3%. This indicates that while FA slightly improves flowability, SF reduces it, with higher SF content leading to excessive thickening, which may impact the workability and pumpability of the grout. The flow results are comparable to other studies that utilize different supplementary cementitious materials, such as pumice stone ash, marble dust, and date palm ash [4, 15, 16].

Figure 1: Flow value of cement grouts containing fly ash and silica fume



3.2 Compressive and flexural strength results

The compressive strength results of cement grouts incorporating fly ash (FA) and silica fume (SF) at 1, 7, and 28 days of curing are compared with the target strengths of 10 MPa, 35 MPa, and 60 MPa, respectively as shown in Figure 2. At 1 day, all grout mixtures exceed the target strength, with values ranging from approximately 25 MPa to 30 MPa, indicating early strength development. At 7 days, all mixtures meet or exceed the 35 MPa target, with the highest strength observed in the 10% FA mix (~50 MPa), showing a 43% increase over the target. At 28 days, the control and modified grouts surpass the 60 MPa target, with the highest value (~70 MPa) achieved in the 10% FA mix, which represents a 16% increase. SF-modified grouts also exhibit strength enhancement, though slightly lower than the 10% FA mix. This trend suggests that FA contributes to long-term strength gain, while SF enhances early and overall strength, making both beneficial for grout performance. The observed improvement in compressive strength with increasing fly ash and silica fume content in the present study is consistent with findings from previous research. Several studies have demonstrated that incorporating proportions of fly ash and silica fume as partial replacements for cement in mortar and concrete enhances compressive strength. This improvement is primarily attributed to the pozzolanic reactions of these supplementary cementitious materials, which contribute to the formation of additional calcium silicate hydrate (C-S-H) gel, thereby refining the microstructure and increasing overall strength [9, 17-22].

The flexural strength of cement grouts at 28 days curing is evaluated against the target strength of 7 MPa. The flexural strength results are presented in Figure 3. The control mix achieves a flexural strength of approximately 7 MPa, meeting the target. The inclusion of 5% FA significantly enhances flexural strength to around 9 MPa, representing a 28% increase over the target. The 10% FA mix shows improvement, reaching about 8 MPa (14% above the target). Similarly, grouts incorporating SF demonstrate improved flexural strength, with the 5% SF mix attaining approximately 7.5 MPa (7% higher than the target), while the 10% SF mix reaches around 8 MPa (14% increase). These results indicate that both FA and SF contribute positively to flexural strength, with FA showing a slightly higher enhancement, making them beneficial for applications requiring improved tensile performance. The results from this study, along with previous research, consistently demonstrate that the inclusion of fly ash (FA) and silica fume (SF) significantly enhances the flexural strength of cement-based materials. FA additions of 5–10% improved flexural strength by 14–28%, while SF additions of 5–10% resulted in 7–14% increases, attributed to their pozzolanic activity and microstructural refinement. These findings align with studies such as Siddique (2011) and Mazloom et al. (2004), confirming that both FA and SF are effective in improving tensile performance, with FA showing slightly higher enhancement potential [23-25].

Figure 2: Compressive strength of grouts at 1d, 7d and 28d curing

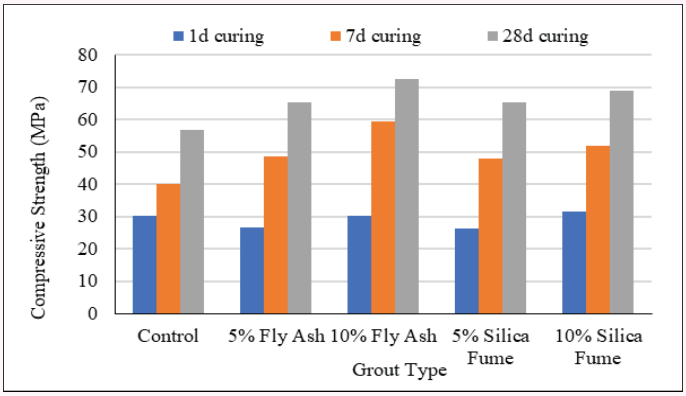
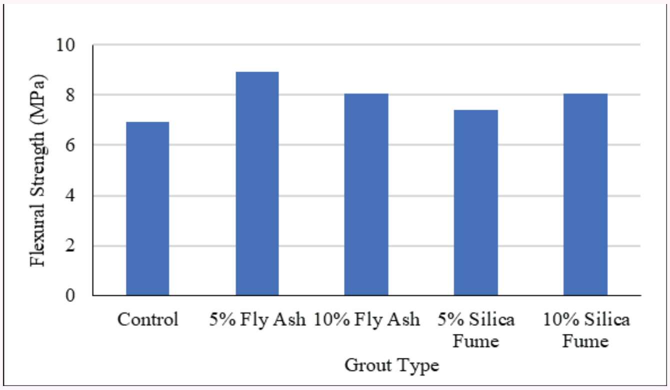


Figure 3: Flexural strength of cement grouts at 28d curing



This study has practical applications in the construction of semi-flexible pavements. Large quantities of fly ash and silica fume are generated as industrial byproducts, and due to their pozzolanic properties, they can be effectively utilized as partial replacements for cement. Furthermore, this type of pavement is specialized for areas subjected to heavy vehicular loads, making it suitable for applications such as urban metro bus routes, bus terminals, industrial parking lots, airport taxiways, and hangars.

Conclusions

This study explored the use of fly ash (FA) and silica fume (SF) as partial replacements for ordinary Portland cement in cement grouts for semi-flexible pavement (SFP) applications. The key findings are as follows:

Fly ash improved the flowability of grouts, with

10% FA reducing flow time by 12% compared to the control. In contrast, SF increased flow time, with 10% SF exceeding the acceptable range, indicating potential challenges in workability and pumpability at higher concentrations.

Compressive Strength: Both FA and SF enhanced compressive strength at all curing ages. FA demonstrated superior long-term strength, with 10% FA achieving a 16% increase in 28-day compressive strength compared to the control. SF contributed to early strength development, with all SF-modified grouts exceeding target strengths at 1 and 7 days.

Flexural Strength: FA and SF significantly improved flexural strength, with 5% FA showing the highest enhancement (28% above the target). SF also contributed positively, with 10% SF achieving a 14% increase over the target.

Environmental and Practical Implications: The use of FA and SF as partial cement replacements offers a sustainable solution to reduce the environmental impact of cement production while maintaining or enhancing grout performance. FA, in particular, stands out for its ability to improve both flowability and mechanical properties, making it a promising alternative for SFP applications.

This study demonstrates the viability of incorporating industrial by-products like FA and SF into cement grouts for SFP, providing a pathway toward more sustainable and high-performance pavement systems. Future research should focus on optimizing replacement ratios and exploring additional by-products to further enhance environmental and mechanical benefits.

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Nanomaterials for slow- and controlled-release fertilizers: innovations for sustainable agriculture

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Abstract:

The pressing need to enhance agricultural productivity while reducing environmental damage has catalyzed the development of innovative fertilizer technologies. Conventional fertilizers suffer from low nutrient use efficiency, resulting in nutrient losses and ecological degradation. Nanotechnology offers a transformative approach through the formulation of slow- and controlled-release fertilizers using functional nanomaterials. These materials, ranging from metal oxides and nanoclays to biopolymers and hybrid composites, enable precise, sustained nutrient delivery in response to environmental triggers such as pH, temperature, and enzymatic activity. Such systems not only optimize nutrient uptake by crops but also reduce application frequency and environmental pollution. This review outlines the properties and classifications of nanomaterials used in fertilizer systems, explains their mechanisms of nutrient release, and highlights recent advancements in synthesis techniques. Additionally, the review discusses key benefits, applications in agriculture, and challenges related to cost, regulation, and scalability. Nanomaterial-based fertilizers hold significant promise for fostering sustainable and efficient agricultural practices.

Keywords: Nanofertilizers; Controlled-release; Slow-release; Sustainable agriculture; Nanomaterials

1. Introduction

The global demand for food continues to rise amid growing concerns about the environmental impacts of modern agriculture. Conventional fertilizers, while critical for crop productivity, exhibit significant inefficiencies. A large portion of applied nutrients, particularly nitrogen and phosphorus, is lost through volatilization, leaching, and runoff. These losses not only reduce nutrient use efficiency (NUE) but also contribute to soil degradation, water eutrophication, biodiversity loss, and greenhouse gas emissions. Estimates suggest that nitrogen use efficiency often falls below 50%, while phosphorus use efficiency is typically less than 25% [1].

In response, there is an urgent need for fertilizer technologies that improve nutrient delivery and reduce ecological harm. Nanotechnology has emerged as a promising strategy, offering tools to engineer fertilizers with enhanced control over nutrient release [2]. By integrating nanomaterials into fertilizer formulations, it becomes possible to synchronize nutrient availability with plant uptake, thereby improving efficiency and minimizing environmental impact [3].

Nanomaterials, such as metal oxides, nanoclays, and polymeric nanoparticles, possess distinct physicochemical properties, including high surface area, reactivity, and tunable functionality. These features make them ideal for use in slow- and controlled-release fertilizers [1]. In particular, nano-enabled fertilizers can be designed to release nutrients in response to environmental stimuli such as soil pH, moisture levels, or enzymatic activity. This targeted release not only supports optimal plant growth but also reduces the frequency of fertilizer applications and mitigates nutrient runoff [4].

This short review explores the role of nanomaterials in the development of advanced fertilizer systems. It categorizes the major types of nanomaterials used, discusses their synthesis and release mechanisms, and highlights their advantages and applications in the context of sustainable agriculture. The review also addresses key challenges and future directions necessary for the large-scale adoption of nano-enabled fertilizers.

2. Types of Nanomaterials in Fertilizers

Figure 1 represents the summary of types of nanomaterials used for the production of controlled-release fertilizers. Nanomaterials employed in fertilizer formulations can be broadly grouped into three categories: inorganic nanomaterials, organic nanomaterials, and hybrid nanocomposites. Each class exhibits distinct properties that influence their behavior as nutrient carriers and their suitability for controlled or slow-release applications [5].

2.1 Inorganic Nanomaterials

Inorganic nanomaterials have garnered substantial interest in agricultural applications due to their stability, high surface area, and capacity for sustained nutrient delivery. Common examples include nanoclays, metal oxides, and mesoporous silica nanoparticles [5].

Nanoclays: such as montmorillonite, kaolin, and attapulgite, are layered silicate minerals recognized for their strong adsorption capabilities and expansive surface areas. These properties make them effective carriers for macronutrients like phosphorus and micronutrients such as zinc [6]. Nanoclay-based formulations have demonstrated enhanced nutrient immobilization; preventing leaching and improving crop uptake, especially in cereal crops. Moreover, combining nanoclays with bio-based polymers has shown promise in increasing soil water retention in arid environments [7].

Metal oxide nanoparticles: including zinc oxide (ZnO), iron oxide (Fe_2O_3), and manganese oxide (Mn_2O_3), are widely used for micronutrient supplementation. These nanoparticles can be engineered to release nutrients in response to environmental cues such as temperature or pH [3]. For instance, zinc oxide nanoparticles have been linked to improved enzyme activity and protein synthesis in plants, while iron and manganese oxides enhance growth under nutrient-deficient conditions [6].

Mesoporous silica nanoparticles (MSNs): MSNs are another prominent inorganic material used for controlled-release purposes. Their tunable pore structures and large surface areas enable efficient nutrient loading and prolonged release. Functionalization of MSNs with biomolecules such as phytase can further regulate nutrient availability, especially for phosphorus. Hybridization of MSNs with polymers has also been shown to enhance their delivery efficiency and reduce environmental impact [8].

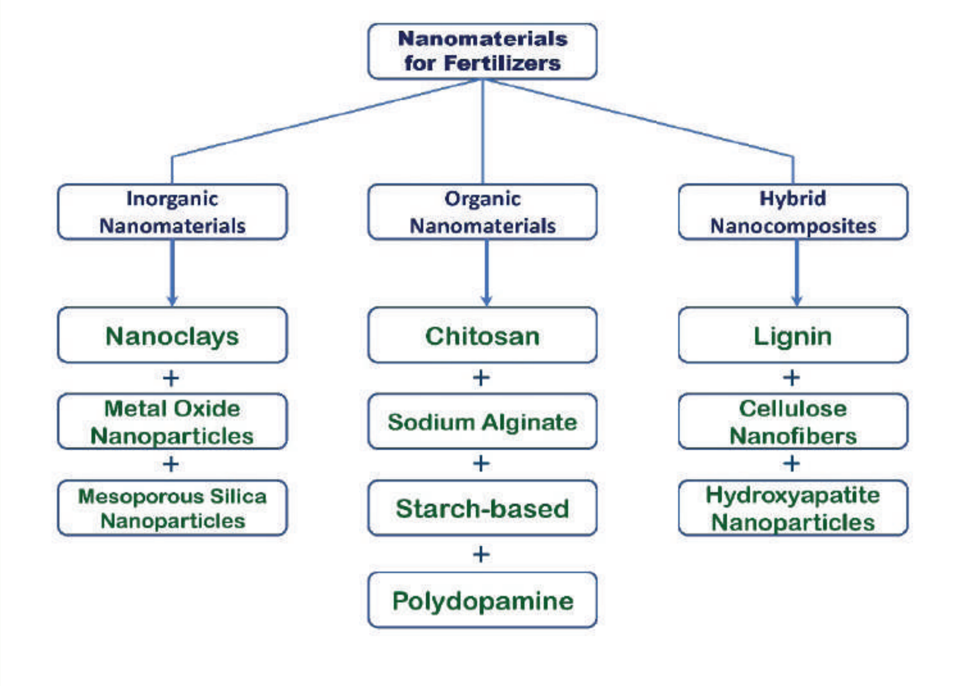

Figure 1: Classification of nanomaterials for the production of controlled-release fertilizers

2.2 Organic Nanomaterials

Organic nanomaterials, particularly those derived from natural polymers, offer environmentally friendly alternatives for nutrient delivery. Their biodegradability and compatibility with soil ecosystems make them ideal for sustainable agricultural practices [1].

Chitosan, a cationic polysaccharide obtained from chitin, is one of the most studied organic nanomaterials in agriculture. Chitosan nanoparticles (CNMs) are known for their strong interaction with plant tissues and their ability to encapsulate key nutrients such as nitrogen, phosphorus, and potassium. These nanocarriers enable gradual nutrient release, enhancing uptake and minimizing losses [10]. Additionally, chitosan exhibits antimicrobial activity, which contributes to improved plant health and resistance to pathogens. Blending chitosan with polymers like polyvinyl alcohol (PVA) improves its mechanical strength and prolongs the release profile [11].

Sodium alginate, extracted from brown seaweed, is another polysaccharide widely used for its gel-forming ability and water-retention characteristics. It serves as an effective coating material for potassium-based fertilizers and can be combined with calcium ions to form hydrogels that control nutrient diffusion. Alginate-based systems are especially useful in water-limited regions. Starch, a naturally abundant and biodegradable polymer, has also been utilized for slow-release fertilizer coatings [7].

Starch-based nanoparticles can encapsulate various nutrients and degrade gradually in soil, offering a consistent supply of macronutrients while minimizing leaching. Composite formulations with starch and PVA have been shown to improve structural integrity and enhance moisture retention [9].

Polydopamine, a synthetic polymer inspired by mussel adhesive proteins, is another promising organic nanomaterial. It forms uniform, thin coatings around fertilizer particles, and its thickness can be controlled to modulate nutrient release rates. These coatings also improve nutrient bioavailability and contribute to better plant performance [12].

2.3 Hybrid Nanocomposites

Hybrid nanocomposites are designed by combining organic and inorganic components to harness the benefits of both material types. These composites offer enhanced mechanical strength, environmental responsiveness, and biocompatibility, making them well-suited for advanced fertilizer applications [13]. Followings include some of the examples:

Lignin, a natural aromatic polymer, can be combined with brochantite, a copper-based mineral, to create nanocomposites that not only deliver micronutrients but also exhibit antimicrobial properties, offering dual benefits of fertilization and disease control [10]. Lignin-based hybrids have been shown to reduce the ecological burden of conventional copper-based pesticides.

Cellulose nanofibers, another biopolymer, have been integrated with inorganic materials to develop nanocomposites with high porosity and customizable nutrient release profiles. These materials have been employed to deliver both nutrients and pesticides, contributing to enhanced crop protection and sustained nutrient availability [14].

Hydroxyapatite nanoparticles (HANPs); the incorporation of HANPs into hybrid formulations with urea and trace elements such as zinc, copper, and manganese. These composites enable the simultaneous delivery of macronutrients and micronutrients in a regulated manner, improving nutrient availability and promoting higher crop yields [15].

Hybrid nanomaterials have also been used to engineer smart fertilizers that respond to changes in soil conditions such as moisture, pH, or microbial activity. A notable example includes a composite made from mesoporous silica and amino-functionalized palygorskite/Fe_3O_4, which demonstrates temperature-sensitive release of iron, ensuring nutrient availability during periods of active plant growth [16].

3. Mechanisms of Nutrient Release from Nanofertilizers

The core objective of nano-enabled fertilizers is to align nutrient availability with the physiological needs of plants, thereby enhancing nutrient use efficiency and minimizing environmental losses. Depending on the design, nanomaterials release nutrients through either slow-release or controlled-release mechanisms [1]. Both approaches contribute to reducing nutrient leaching, volatilization, and runoff, especially under varying environmental conditions. Figure 2 illustrates the mechanism of nitrogen release from controlled-release urea.

3.1 Slow-Release Systems

Slow-release mechanisms are based on physical encapsulation or structural immobilization of nutrients, leading to a gradual release over time, regardless of external stimuli. These systems rely primarily on the inherent degradation rate of the carrier material or its solubility in soil moisture [12].

Encapsulation and Matrix Degradation: In many formulations, nutrients are embedded within or coated by biodegradable polymers such as starch, chitosan, or alginate. As these materials degrade in the soil, due to microbial activity or hydrolysis, nutrients are progressively released. For example, starch-coated urea particles allow for a sustained nitrogen supply by resisting rapid dissolution [17].

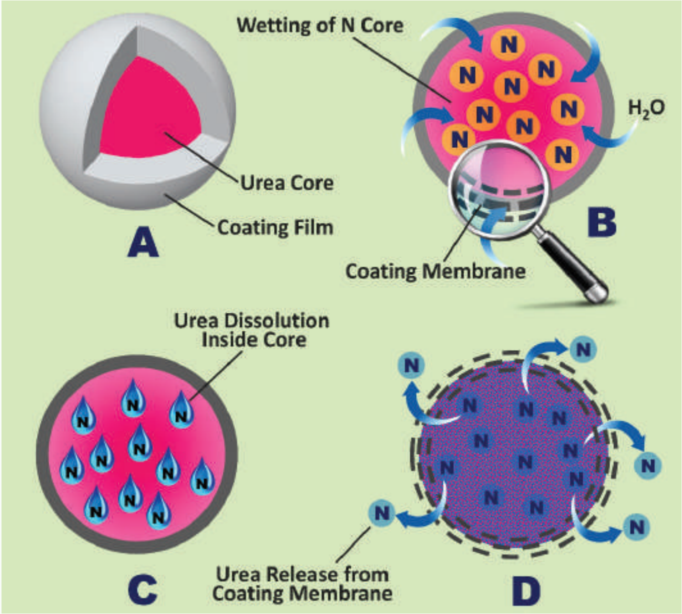

Figure 2: Mechanism of nutrient-release at different .stages from controlled-release urea

Hydrogel-based Release: Hydrogels formed from materials like sodium alginate and chitosan serve as absorbent carriers that release nutrients slowly as they swell and degrade. Their high water-retention capacity is particularly beneficial in water-scarce environments. These materials can retain and gradually deliver nitrogen, phosphorus, and potassium, improving their availability throughout the plant growth cycle [9].

Inorganic Immobilization: Materials like hydroxyapatite (HA) and montmorillonite clay can immobilize macronutrients such as phosphorus. Their slow dissolution or ion-exchange mechanisms enable a steady release of nutrients while also minimizing fixation or leaching. For instance, hydroxyapatite-based fertilizers have shown a gradual release of phosphorus over several weeks, enhancing root development in crops [18].

3.2 Controlled-Release Systems

Controlled-release systems differ from slow-release systems by incorporating smart mechanisms that respond to specific environmental triggers such as soil pH, temperature, and enzymatic activity. These stimuli-responsive systems offer more precise nutrient delivery, closely aligned with plant uptake patterns [19].

pH-Responsive Systems: In many soils, pH significantly influences nutrient availability. Fertilizers coated with pH-sensitive polymers such as alginate or chitosan undergo swelling or dissolution depending on soil acidity or alkalinity. For instance, alginate-based potassium fertilizers have shown increased release rates in acidic conditions, making them suitable for soils with low pH where potassium mobility is often limited [13].

Temperature-Responsive Carriers: Temperature-sensitive materials are designed to release nutrients at higher temperatures that coincide with peak plant growth periods. Composite materials such as amino-functionalized palygorskite and Fe_3O_4 encapsulated within mesoporous silica exhibit thermal responsiveness. These systems can increase iron availability when ambient temperatures rise, ensuring nutrient release matches active plant metabolism [9].

Enzyme-Triggered Systems: Soil enzymes, particularly those secreted by microbial populations and plant roots, can degrade nanocarriers and trigger nutrient release. This site-specific degradation ensures that nutrients such as nitrogen and phosphorus are made available primarily in the rhizosphere, where they are most needed [20]. For example, phytase-functionalized mesoporous silica nanoparticles have been developed to release phosphorus only in the presence of phytate, a natural phosphorus compound in soil, thus avoiding unnecessary losses.

Multi-Stimuli Responsive Nanomaterials: Some advanced formulations integrate two or more environmental triggers to enhance precision. One such system combines pH and temperature sensitivity in a composite nanocarrier, ensuring that nutrients are released only under optimal growing conditions [21]. This dual responsiveness further refines nutrient delivery timing, reduces waste, and enhances crop productivity.

The development of these controlled-release systems marks a significant step forward in precision agriculture. By utilizing environmental cues, these systems can respond dynamically to fluctuating field conditions, offering nutrients in real time according to crop demand.

4. Applications and Benefits of Nano-Enabled Fertilizers

Nano-enabled fertilizers have demonstrated significant promise in agricultural applications by enhancing nutrient delivery, minimizing environmental losses, and improving overall crop productivity. Their ability to deliver nutrients in a controlled or sustained manner contributes to increased nutrient use efficiency, reduced environmental footprint, and greater economic returns for farmers [13].

4.1 Enhanced Nutrient Use Efficiency (NUE)

One of the most notable advantages of nanomaterials in fertilizer formulations is their contribution to improving nutrient use efficiency (NUE). The controlled release of nutrients ensures their availability during critical growth stages, which reduces wastage and enhances plant uptake. For example, nitrogen fertilizers encapsulated in chitosan or starch matrices release nutrients gradually, which aligns with the nitrogen demand of the plant over time [21]. This prevents excessive nitrate accumulation in the soil and minimizes losses through leaching or volatilization. Similarly, hydroxyapatite-based nanofertilizers release phosphorus at a regulated rate, maintaining its availability near the root zone, which is particularly beneficial given phosphorus's tendency to become fixed in soil [22].

Zinc oxide nanoparticles, when applied to crops, enhance physiological processes like chlorophyll synthesis and enzyme activation. Their nano-size facilitates easier penetration into plant tissues, resulting in improved micronutrient uptake and better plant performance [16]. Additionally, hybrid formulations delivering zinc, manganese, and copper together have been shown to correct micronutrient deficiencies more effectively than conventional fertilizers [22].

4.2 Environmental Sustainability

Nanomaterial-based fertilizers contribute to environmental protection by mitigating the adverse effects associated with traditional fertilization practices. The use of slow- and controlled-release formulations reduces the frequency of fertilizer application, thereby lowering fuel consumption and greenhouse gas emissions from farm operations [23]. More importantly, controlled nutrient release significantly reduces leaching and runoff, especially in the case of nitrogen and phosphorus. This is critical in preventing eutrophication of nearby water bodies and reducing nitrate contamination of groundwater [20].

Furthermore, nanocarriers based on biodegradable polymers such as chitosan and alginate decompose in soil without leaving harmful residues, unlike conventional polymer-coated fertilizers that may leave persistent synthetic materials behind. Inorganic carriers like montmorillonite and hydroxyapatite, although not biodegradable, are naturally occurring and environmentally benign [24]. The use of nanofertilizers also enhances the retention of nutrients in the rhizosphere, reducing the need for high application rates and thereby limiting the accumulation of excess salts and chemicals in the soil. This supports long-term soil health and fertility [11].

4.3 Economic Benefits

From an economic standpoint, nanofertilizers can lead to cost savings over time, despite potentially higher initial production costs. The reduction in nutrient losses and application frequency translates into lower input costs and labor requirements. Farmers using nano-enabled fertilizers benefit from higher yields and improved crop quality [18]. Enhanced nutrient availability results in better root development, higher chlorophyll content, and improved grain or fruit filling. In turn, this improves the marketability and economic value of produce [22].

In addition, certain nanofertilizers offer dual benefits, acting as both nutrient carriers and disease suppressants. For instance, lignin-based nanocomposites with copper minerals not only supply essential micronutrients but also exhibit antimicrobial properties, reducing the need for separate pesticide applications. In field trials, the application of nanofertilizers in crops such as maize, wheat, rice, and tomato has consistently demonstrated improvements in yield, plant health, and resource efficiency. These benefits make nanoformulated fertilizers an appealing choice for both conventional and resource-constrained farming systems [25].

5. Challenges and Future Outlook

Despite their potential, the widespread adoption of nanofertilizers is limited by challenges related to cost, safety, regulation, and awareness. High production expenses and difficulties in scaling up synthesis methods hinder commercialization, although green synthesis approaches offer promise. Safety concerns persist due to the unknown long-term effects of some nanomaterials on soil ecosystems and human health. The absence of standardized testing protocols and regulatory frameworks further complicates their approval and market acceptance. Additionally, limited awareness among farmers and public skepticism about nanotechnology in agriculture pose barriers to adoption. Building trust through outreach, education, and transparent communication is essential. Looking ahead, research should focus on multifunctional and smart nanofertilizers capable of responding to environmental signals for precision nutrient delivery. Integrating these innovations with digital agriculture tools and securing institutional support through policies and incentives will be key to realizing the full potential of nanofertilizers in sustainable farming systems.

6. Conclusion

Nanomaterials offer transformative potential for developing slow- and controlled-release fertilizers that enhance nutrient use efficiency, reduce environmental impact, and support sustainable agriculture. By tailoring nutrient delivery to plant needs through smart release mechanisms, these materials address the limitations of conventional fertilizers. Inorganic, organic, and hybrid nanomaterials each contribute unique benefits, with demonstrated success in field applications. Despite existing challenges related to cost, safety, and regulation, continued research and supportive policies can facilitate their broader adoption. As agriculture evolves toward precision and sustainability, nano-enabled fertilizers are poised to play a vital role in the future of food production.

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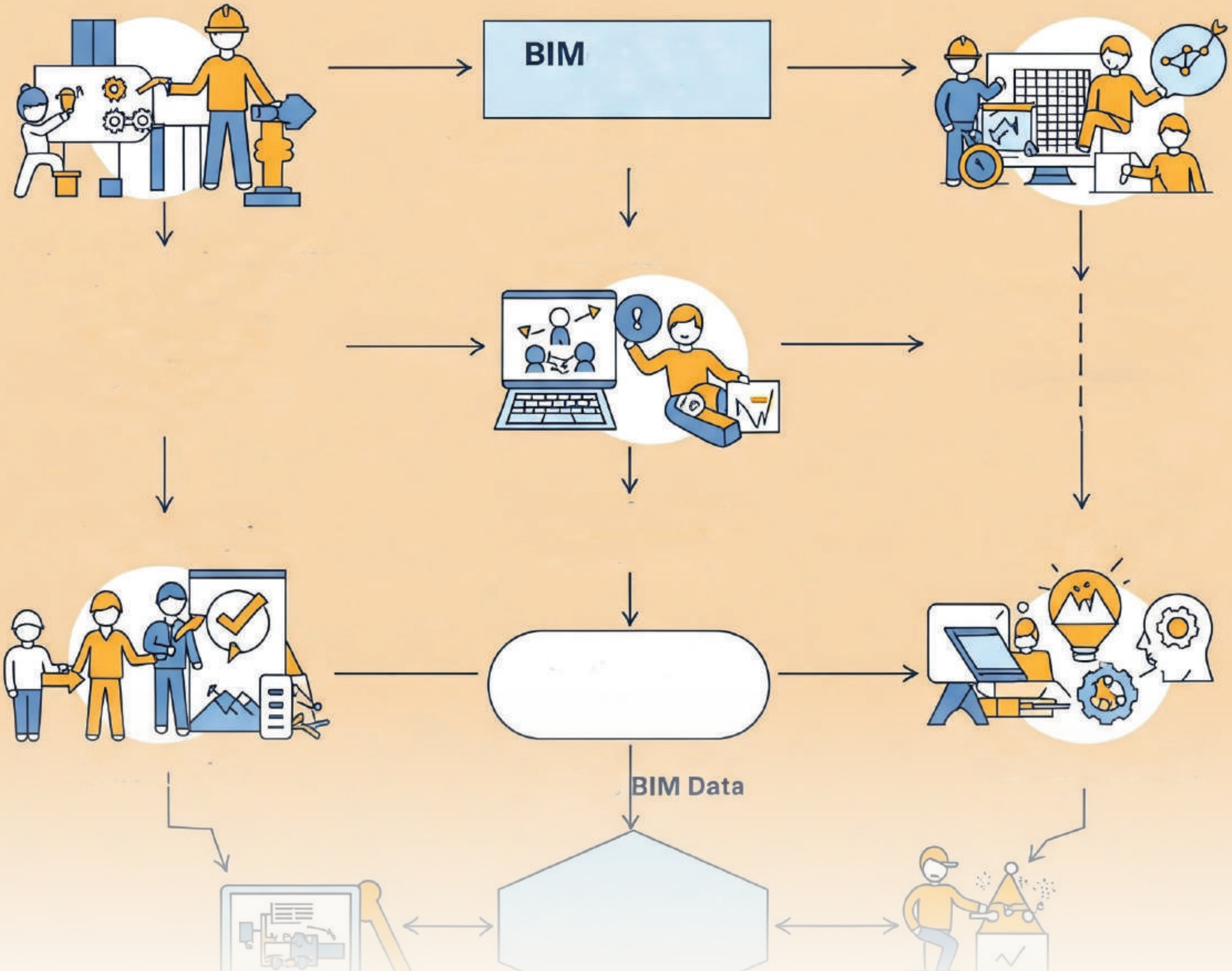

A BIM-BASED JOBSITE SAFETY PLANNING FRAMEWORK FOR SMALL-TO-MEDIUM SIZE CONSTRUCTION FIRMS

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Abstract

Jobsite safety has always been a top priority in the construction industry. Although remarkable improvements have taken place in construction technologies and processes in recent years, the safety records in the construction industry continue to be one of the poorest. Unsafe jobsite conditions, inappropriate work planning, insufficient communication between workers and supervisors, and lack of safety training are some of the key contributing factors. Most construction firms typically use 2D projects drawings for preparing a jobsite safety plan. This method is not very effective to properly identify all hazards on a jobsite. Building Information Modeling (BIM) is a recent technology that is now effectively used by construction firms of all sizes in the USA and other parts of the world for project planning, execution, and control. The BIM technology can also assist in improved safety planning by allowing site engineers and managers to visually assess jobsite conditions and identify all possible hazards before the construction begins. By using digital 3D models and time-lapse 4D simulations, the project team can more effectively design, communicate and implement a jobsite safety plan. BIM-based safety planning is used by several large-size construction firms in the USA but most small-to-medium size firms are still evaluating its cost, benefits and implementation challenges. This research study presents a four level progressive framework for small-to-medium size construction firms to assist them for incorporating BIM in the safety planning and management process. Necessary data for this research was collected via case studies, and interviews with BIM and safety experts. It is hoped that the findings presented in this paper will be helpful to both researchers and practitioners that are working in the area of safety planning and management.

Keywords: Building Information Modelling (BIM); Jobsite safety; Construction hazards; Safety planning; Safety management.

1. Introduction

Construction operations are typically risky because of complex outdoor and at-heights work, complicated and often very tight jobsites, hazardous materials and equipment operations, and unpredictable human behavior (Choudhry et al. 2007). Accidents on construction sites occur either due to lack of knowledge or training, a lack of supervision, or a lack of means to carry out the task safely, or alternatively, due to an error of judgment, carelessness, or apathy (Fang et al. 2004). Studies have shown that hazards can be controlled and accidents can be prevented through the implementation of basic safety practices leading to a sound safety program (Choudhry et al. 2007). Safety planning is an essential part of the construction planning process. Despite rigorous efforts of safety professionals and strong governmental reinforcement of safety laws and regulations, there has not been a significant decline in the frequency and severity of injuries and illnesses in the construction industry. Research on workplace fatalities and injuries in construction concludes that the major safety problems are associated to falls, electrocution, struck-by, and caught in/between objects (Goetsch 2012). Unsafe jobsite conditions, inappropriate work planning and supervision, insufficient communication between different partners and lack of safety training are identified as key contributing factors behind most fatalities and injuries (Martinez-Aires et al. 2018).

Several inspiring technologies have been developed in the last few decades to improve workplace safety in construction. However most construction firms still use Computer-Aided Design (CAD) based 2D drawings to plan for safety. The CAD-based systems represent a static and isolated design process. While the CAD-based drawings provide a topological description of buildings in the way different objects are connected together and store specific architectural features and attributes, they are not suitable for properly identifying construction hazards at jobsites due to the following reasons: (1) they do not provide a holistic view of the construction jobsite that can guide safety planners to ascertain all possible hazards; (2) they provide a static view of a construction jobsite whereas construction sites are dynamic and nature of hazards varies as the work proceeds; and (3) they are not intuitive and it is easy to miss out minor details that could have a big impact on safety planning (Azhar et al. 2012a; Rozenfeld et al. 2009). Figure 1 shows a comparison of a 2D CAD drawing with a 3D model to plan for crane safety on a construction jobsite. From this comparison, one can easily conclude that a 3D model is more intuitive to fully understand a construction jobsite for hazards identification than its 2D counterpart.

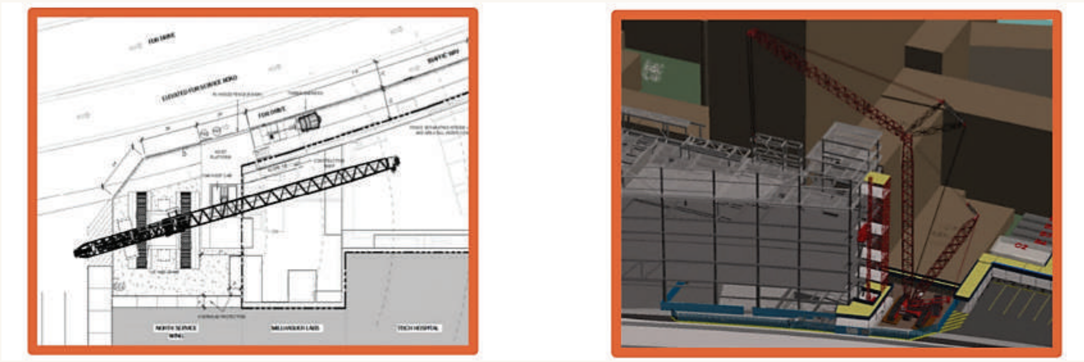


Figure 1. A comparison of a 2D drawing with a 3D model for crane safety planning (Chiusano 2012)

Presently, the most thriving technology in the construction industry is Building Information Modeling **(BIM)** (Martinez-Aires et al. 2018). BIM is a revolutionary technology that enables architecture, engineering, construction, and facility management professionals to more efficiently plan, design, construct, and manage buildings and infrastructure (Autodesk 2018). BIM represents the development and use of a 3D/4D computer model(s) to simulate the planning, design, construction and operation of a facility. The resulting digital model, called as a Building Information Model (hereinafter referred as a BIM model), is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility (AGC 2005). Table 1 summarizes the BIM applications for various project stakeholders throughout the construction life cycle.

Table 1. BIM applications for project stakeholders (Adapted from Azhar et al. 2012b)

BIM Application	Owners	Designers	Contractors	Facility Managers
Visualization	x	x	x	x
Design analysis	x	x	x	
Sustainability analyses	x	x	x	x
Quantity surveying		x	x	
Cost estimation	x	x	x	
Site safety planning	x		x	
Site logistics planning			x	
Phasing and 4D scheduling		x	x	
Constructability analysis		x	x	

Building performance analysis	x	x	x	x
Building maintenance	x			x
Building management	x			x

The BIM technology can be used as an innovative and collaborate tool for improved safety planning and management. Azhar (2017) outlined the following areas where safety professionals can use BIM technology: (1) Worker safety training and education; (2) Design for safety; (3) Safety planning (i.e. job hazard analysis and pre-task planning); (4) Accident investigation; and (5) Facility maintenance safety. For these tasks, the safety professionals can use 3D BIM models and walk-through animations. In addition, the 4D phasing simulations focused on the safety procedures can be generated to show how temporary safety elements and areas of concerns transition throughout the duration of a project. These types of simulations can be particularly helpful on risky and complex construction projects. The utilization of BIM technology can result in improved occupational safety by connecting the safety issues more closely to construction planning, providing more illustrative site layout and safety plans, providing methods for managing and visualizing up-to-date plans and site status information, as well as by supporting safety communication in various situations, such as informing site staff about making safety arrangements or warning about risks. The use of BIM also encourages other project partners to involve both in risk assessment and planning throughout the project execution. These partners are designers, sub-contractors, safety specialists, and occupational health care professionals (Sulankivi et al. 2009).

At present, several large-size construction firms routinely use BIM for safety planning and management as part of their overall BIM implementation strategy in the project life cycle (de Robles et al. 2016). However, most small-to-medium size construction firms are found to use traditional methods for safety planning and management. The anecdotal evidence suggests that many of these firms are using BIM for selected applications (such as visualization, clash detections, project coordination) but have not fully implemented it throughout the project life cycle. It is also found that several firms are unsure how to effectively implement BIM for jobsite safety planning and management (de Robles et al. 2016). This research study is conducted with three objectives in mind: (1) to find out the state-of-the-art of BIM usage for safety planning and management in small-to-medium size firms; (2) to identify BIM applications that are most useful for jobsite safety planning through case studies; and (3) to develop a progressive framework that can guide small-to-medium size firms to effectively deploy BIM technology for safety planning and management. The related data for this research is collected from construction firms based in the Southeast USA, however most of the presented results are applicable to construction companies of similar characteristics in other parts of USA and worldwide.

2. Research Design and Methodology

To explore the applications and best practices of Building Information Modeling (BIM) for jobsite safety planning, case studies were conducted involving three medium-sized construction firms that either currently use or have previously utilized BIM for safety planning, management, and control. Utilizing data gathered from these case studies, a progressive framework consisting of four Levels of Detail (LODs) is developed specifically for small-to-medium-sized construction firms. This framework aims to systematically guide such firms in implementing BIM effectively for safety planning and management.

3. Results and Discussion

3.1. Case Studies

Case Study 1: A Hospital Building, Fort Benning, Georgia

The first case study is a USD 380 Million, 745,000 ft^2 hospital building located in Fort Benning, Georgia. Jobsite safety planning was not in the original scope for BIM services. The safety manager and the site superintendent made the decision to try and utilize BIM in their safety program for the following applications: (1) Identifying hazards and visualizing tasks with high safety concerns; (2) Illustrating clearances; (3) Crane safety; (4) Location of fire extinguishers; and (5) Fall protection. During the pre-construction stage, the safety manager and project engineers were able to use the BIM model to identify certain safety hazards that must be quickly addressed. These included overhead obstructions, falling objects, entrance locations, and underground obstructions. In addition, through BIM they were able to visualize certain risky tasks such as (1) Equipment access, reach, and landing area locations (see Figure 2); (2) Forklift maneuvering routes; (3) Guard rail positions and where removable sections would be located; and (4) Fall arrest and restraint anchor points.

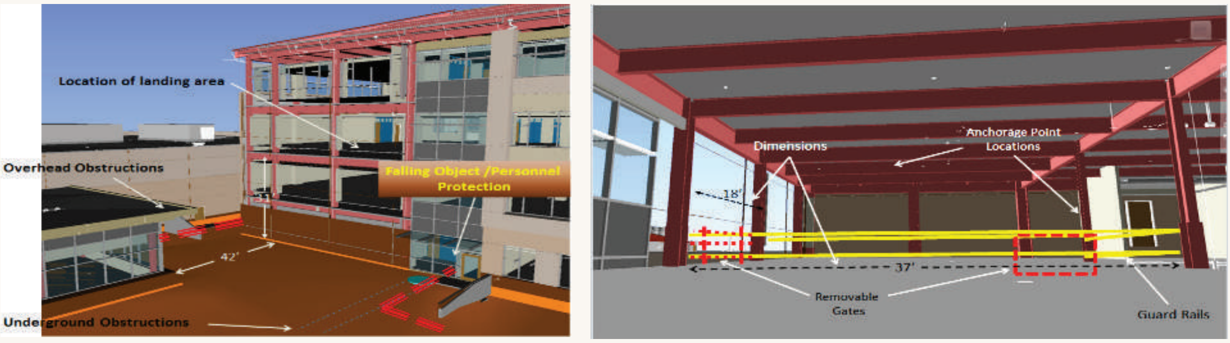


Figure 2. Screenshots of 3D BIM models to mark clearances and areas of safety concerns

The project safety team used BIM to increase crane safety in multiple ways. First, they determined the exact type of crane needed and added it to the BIM model (see Figure 3, left). Then an analysis was performed on the swing radius, height, clearances, and placement of the crane to examine what risks or hazards could arise while the crane would be in use. In one instance it was realized that the crane would not be long enough for a particular task and the contractor arranged a mobile crane before that task began. The safety team also used BIM to determine the locations and number of fire extinguishers that would be needed (throughout the project (see Figure 3, right

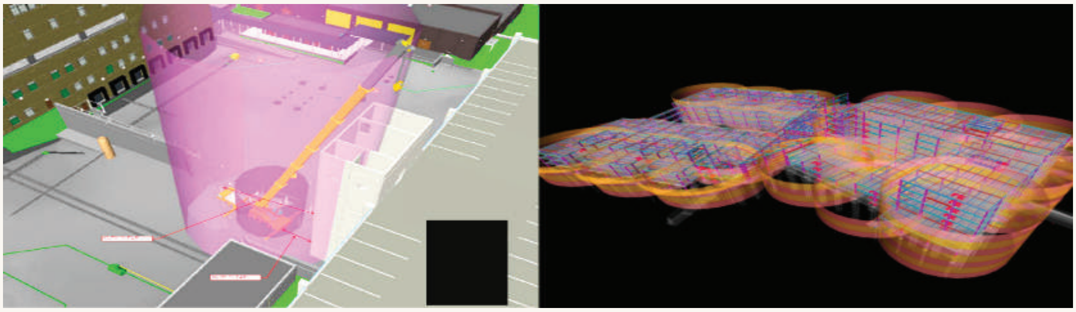


Figure 3. Screenshots of BIM model depicting crane safety (left) and fire extinguishers' placement plan (right)

The safety manager had a meeting with the BIM team to figure out how to utilize the BIM model for the fall protection plan (see Figure 4, left). They determined all the safety guardrails that would be needed, where they would be needed, and added them to the model. Also they determined anchor points that would be needed to support these rails. The project team also used BIM to visualize and model certain tasks in order to determine logistics and safety for complex tasks. One good example was an excavation they modeled in BIM for gas tanks. They used BIM to model the slopes and found that it was not possible to keep the required slope on the excavation in the current place (see Figure 4, right). It was decided to move the tanks eliminating hundreds of hours of work, rework, and possible unsafe conditions. The General Contractor (hereinafter called as the GC) also used the BIM model for subcontractors' orientation. When a new subcontractor came on site, the GC's safety manager sat down with their safety foreman and walked them through the BIM model at the current stage of the project. At that time, he went over any safety concerns, safety exits, or anything else that could be safety related to bring the subcontractor up to speed before their .people even walk on the site

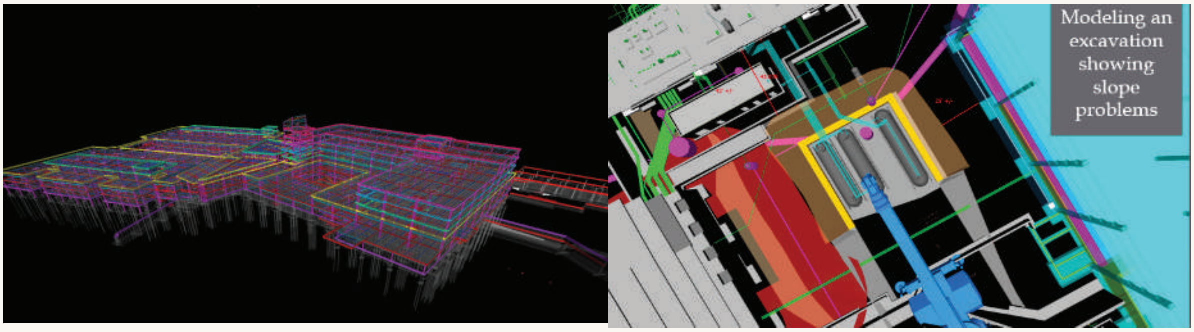


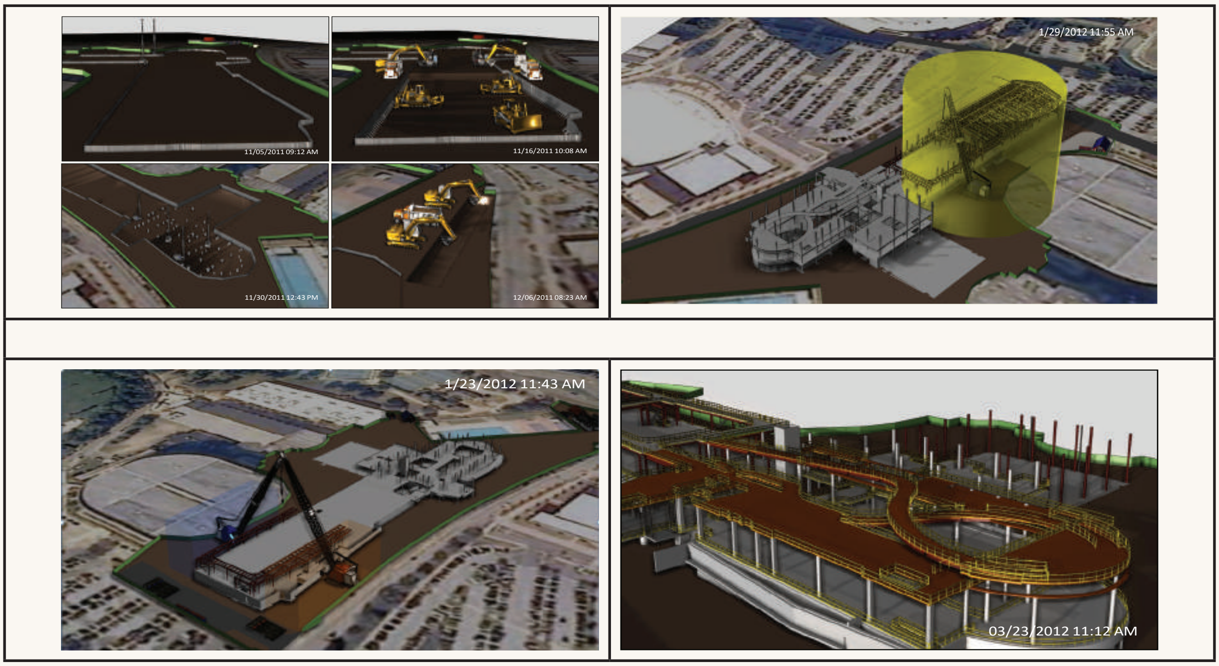
Figure 4. Screenshots of BIM models showing fall protection (left) and slope safety (right) plans

Findings from this case study suggest that BIM models could be effectively used to help with safety training, site layout, hazards identification, communication, collaboration, crane safety, fall protection and slope protection. One of the biggest lesson learned is that there are numerous ways BIM can be utilized to increase the efficiency of safety programs with very little added effort and money. Reader interested to find out more details of this case study are advised to read the following reference (Azhar 2017).

Case Study 2: A Recreation and Wellness Center Building, Auburn, Alabama

The second case study demonstrates the applications of BIM for safety planning and management for a Recreation and Wellness Center project construction. The project cost was USD50 Million and size was approximately 240,000 ft^2. The project team used BIM to address the following jobsite hazards: (1) Excavation cave-ins; (2) Falls; (3) Struck by objects; and (4) Caught in/between equipment. Following five BIM-based safety plans were developed: (1) Excavation risk management plan; (2) Crane safety plan; (3) Fall protection plan for leading edges; (4) Fall protection plan for roofers; and an (5) Emergency response plan. The following end products were developed for the above-mentioned safety plans: (1) 3D renderings; (2) 3D Walk-through and fly-through animations; (3) 4D phasing simulations; and (4) Narrated videos for workers based on animations and simulations.

The purpose of the excavation risk management plan was to safely coordinate earthwork operations at the jobsite. The earthwork phase required 8 ft deep excavation and then installation of sheet piles to avoid cave-ins. In the BIM model, the safety manager created sheet piling components consisting of a sheet pile section and a base re-shoring stand made of a steel beam and a solid steel tube. The sheet piles were arrayed around the indented ditch and the stands were then arrayed behind them. The site utility work included installation of reinforced concrete pipes for sewage. These activities were modeled using 4D simulations to coordinate excavation equipment operations at the jobsite. The crane management plan was prepared to: (1) Identify swing radius of the crane to ensure its safe distance from the power lines and nearby temporary and permanent structures; and (2) Identify what trade/crew would be utilizing crane at a particular day/time. The fall protection plan for leading edges was prepared according to OSHA subpart M: Fall protection standards. Two types of fall protection railings were modeled: 2x4 wooden railings on the second level (concrete structure) that were bolted to the concrete slab and 3/8 inch steel cable railings on the third and higher levels of the project (steel structure). After modeling the fall protection railing components, the railings were added in the BIM model. While preforming this process, the safety team was able to identify multiple fall hazards through the 3D view that were not easily identifiable in the 2D plans such as not yet constructed stairwells and skylights. The modeled railings were then segregated by zones and levels to prepare the 4D simulations. The 4D simulations provided complete installation details to the GC and sub-contractors such as the location and date when the railings were to be installed or removed (see Figure 5).



.**Figure 5.** Screenshots depicting excavation, crane safety, and fall protection plans

Another fall protection plan was prepared for the roof installation. The entire roofing operation was simulated to identify possible safety issues. These simulations were used to brief roof workers about work conditions and hazards on a constantly changing roof structure. The BIM-based emergency response plan consisted of 5 sub-plans namely Construction crew entrance/exit; Construction equipment and deliveries route, Temporary facilities and job trailer locations, Emergency vehicle(s) route, and Severe weather shelters to orient workers with the construction site. Three dimensional (3D) walk-through animations and renderings were generated from the BIM models to communicate emergency response plan to the workers (see (Figure 6

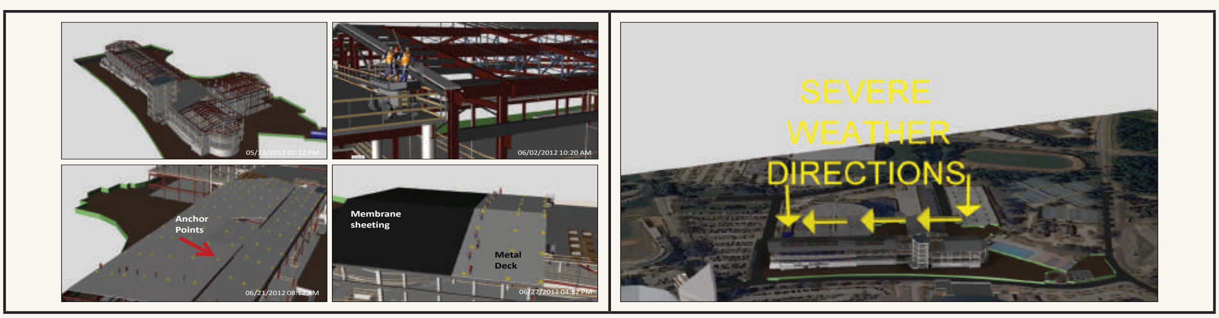


Figure 6. Screenshots depicting fall protection for roofers and severe weather plans

The 3D walk-throughs and renderings, 4D simulations, and animation videos were used by the GC to communicate the site safety plan to the sub-contractors. The site superintendent, site managers, and site safety staff were interviewed to identify the benefits and any pitfalls. The interviewees described three main perceived benefits: (1) improved communication of the safety plan to the construction personnel; (2) improved communication of the project's safety plan to the OSHA and the owner; and (3) logistical details of construction safety tasks being fully addressed in the preconstruction phase. Following are two excerpts from the interviews: (1) "….. BIM technology could have a very significant and positive impact on the safety planning and management…the 4D animations proved to be very helpful in the safety planning meetings and daily safety talks….."; (2) "……4D simulations are very helpful to fully involve owners in the safety process that may not be as fluent at visualizing safety practices from 2D drawings or written safety plans….". The group expressed some concerns on the extra cost that was involved in developing the BIM-based safety models. They also suggested a close collaboration between the BIM modeler(s) and site safety staff to ensure 100% accuracy of the resulting models and simulations.

Case Study 3: A Three-Story Office Building, Birmingham, Alabama

The third case study was a three-story officebuilding located in Birmingham, Alabama. The project cost and floor area are approximately USD 5.5 Million and 19,340 ft^2 respectively. It was a fast-track project with 9-months completion target. The project design firm developed the BIM model of the project and provided it to the GC. The GC reviewed the model and added necessary structural details to perform the site safety and logistics analysis. For safety planning, the BIM model was used for the following applications: (1) Excavation planning; (2) Fall protection measures; and (3) Scaffolding planning.

One of the first identified hazards in the construction work was possible cave-ins during excavation due to presence of soft clays. To keep construction cost minimum, the GC decided not to use any expensive excavation protection methods and instead rely on the "design-for-safety" concept to slope excavations at their natural angles to avoid possible cave-ins. This information was communicated to the excavation sub-contractors using the 3D models such as one shown in Figure 7.

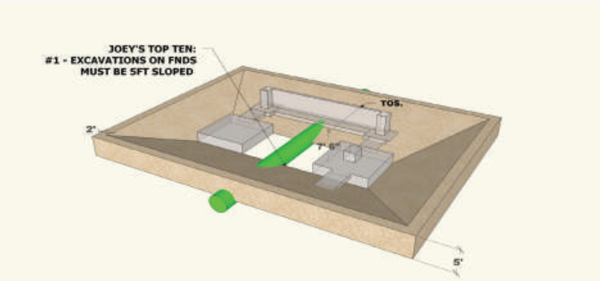


Figure 7. 3D Excavation model outlining slope angle, UG utilities, and foundation layout

For fall protection planning, by using the BIM model the GC identified all leading edges where guardrails must be installed. In addition, the locations of warning cables were also identified. The purpose of warning cables was to warn workers to wear fall protection harnesses before moving further to the open edges. All open areas (such as elevator shafts) were clearly identified using pink color. Safety nets were shown in the blue color (see Figure 8). The GC shared this color coded 3D BIM model with all subcontractors before the construction began. It was also used by GC and sub-contractors during the safety briefs with the workers.

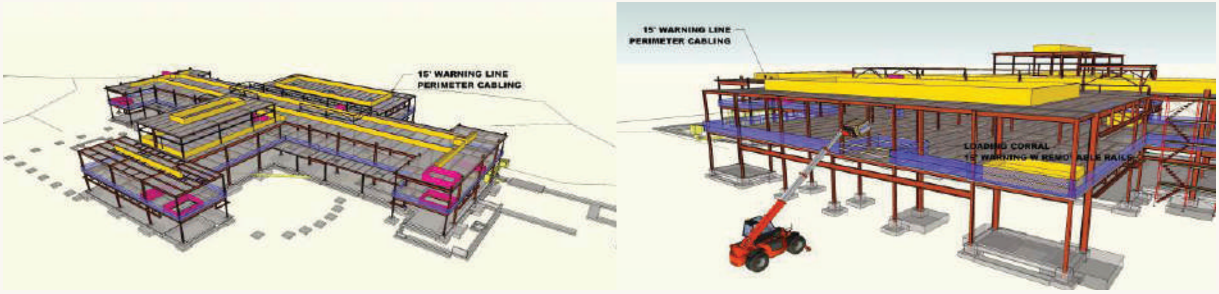


Figure 8. Screenshots of fall protection plan

All scaffolding was modelled and added in the existing BIM model. One main reason for doing so was to clearly mark the areas where scaffolding should be anchored with the existing permanent/temporary structures. The temporary power system was also modelled to inform sub-contractors about the power input areas. In addition, the interior areas where scissor lift should be used instead of scaffolding were also shown in the model. The GC and sub-contractors used these models for site logistic planning (see Figure 9).

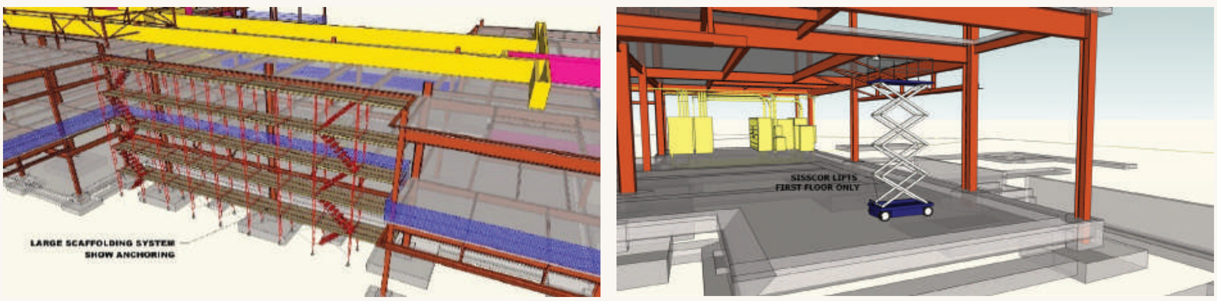


Figure 9. Screenshots showing scaffolding installation plan and scissor lift use areas

Due to precautionary approach of the GC, the project was completed on-time and without any fatality and reportable injuries. The GC and the subcontractors very effectively used the 3D BIM models for jobsite safety planning and logistical analysis. This was the first time that this GC used BIM for site safety planning and realized rich benefits. All BIM-based safety planning was done by the in-house BIM team in consultation with the project safety manager and site superintendent. After this successful experience, the GC is currently using BIM for safety planning in all major projects.

3.2. A BIM-based Jobsite Safety Framework Development

Based on the information collected in this research, a BIM-based framework is developed to guide small-to-medium size companies about BIM deployment for jobsite safety planning and management. The framework is shown in Figure 10.

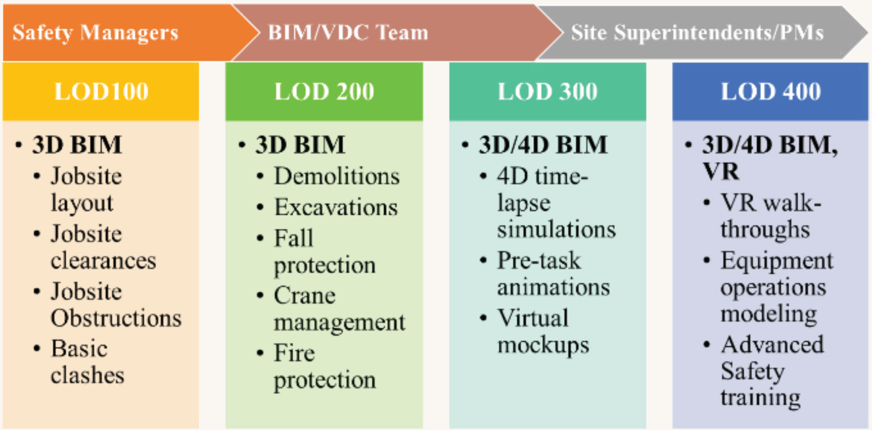


Figure 10. A BIM-based jobsite safety framework for small-to-medium size firms

This progressive framework suggests that small-to-medium size firms can systematically implement BIM for safety planning and management using four Levels of Development (LODs). The description of each LOD is as follows:

LOD 100: Basic Implementation

For this LOD, the firms will need an integrated 3D site and building model. This model can be developed either using BIM or 3D solid modeling tools such as Sketchup®. The model details/layers can be adjusted based on the safety planning needs. Such a model can be used for basic site layout and orientation, marking site clearances and overhead obstructions, and any clashes between temporary and permanent structures. For this LOD, the firms would need professionals with basic knowledge of BIM and/or other 3D modeling software.

LOD 200: Intermediate Level Implementation

At the next development stage, the firms can use BIM models to develop site demolitions, excavation management, fall and fire protection, and crane safety plans. Hazards identification process could be either manual (through brainstorming sessions) or automated (via advanced tools such as Dynamo®). A good example of task automation is to automatically identifying all leading edges and mark positions of guard rails in a BIM model. For this LOD, the firms would need BIM professionals with intermediate-to-advanced knowledge.

LOD 300: Advanced Level Implementation

At this level, the firms can use 3D BIM models and 4D time-lapse simulations for hazards identification and overall jobsite safety planning. For complex tasks, pre-task animations or virtual mockups can be prepared to identify possible hazards in assembly and to explain the work sequence to the construction workers. At this LOD, the firms would need BIM professionals with advanced knowledge.

LOD 400: Superior Level Implementation

In the last level, the firms can use further enhance their BIM-for-safety models using advanced visualization technologies such as Virtual/Augmented/Mixed Reality (VR/AR/MR) for site walk-throughs, equipment operations modeling, and advanced safety training. These visualization technologies will allow construction workers and site engineers to virtually execute certain complex tasks and determine possible hazards before actual implementation. At this LOD, in addition to BIM experts, the companies would need professional with knowledge of VR/AR/MR visualization technologies as well as some programming experience in Unity 3D®, Unreal Engine® or a similar type of gaming software.

3. Conclusions and Recommendations

This research concluded that small-to-medium size construction firms can be greatly benefited from the deployment of BIM technology into their jobsite safety programs. Through 3D BIM models and 4D simulations, the project team members can take effective protective measures in the project planning phase to eliminate (or minimize) the possible jobsite hazards. The case studies proved that 3D/4D BIM models are more helpful in hazards identification than the traditional 2D drawings because they closely simulate the actual jobsite conditions.

It is noted that BIM technology is very useful in creating real-life construction jobsite scenarios thereby ascertaining safety risks is quick and easier. It is found that designers do not have adequate construction safety knowledge, which results in many inherent safety hazard loopholes in the project design. Similarly, it is very hard for contractors to identify all possible hazards in the project planning and preconstruction phases. BIM technology can be used as an interactive and collaborative safety planning tool to address these gaps. In addition, the BIM models are dynamic and truly reflect the hazards at different stages of construction which are otherwise difficult to identify through 2D drawings. Users can also perform "what-if" analysis to determine the impact of a particular construction activity on the overall jobsite safety. The BIM technology has some weaknesses such as it is still evolving and sometimes not very stable. Substantial time is required in learning the new developments in the BIM software. In addition, BIM may not be attractive to project safety team members that are not well versed with the technology. There are numerous opportunities for blending BIM into the safety programs especially for complex projects. As the cost of implementing BIM technology is becoming cheap day by day, it can be envisaged that small-to-medium size construction firms may find it easier to procure and implement it either directly or through outsourcing. BIM and related visualization technologies (e.g. VR/AR/MR) are very effective for workers' training and should be used by firms of all sizes. It is found that most safety managers are not capable to use BIM for safety modeling/simulations development and have to rely on the expertise of the BIM team. This gap can limit the effectiveness of BIM for jobsite safety and may result in overlooking some hazards. A proper check-and-balance process is needed to ensure foolproof deployment of BIM into the firm's safety programs.

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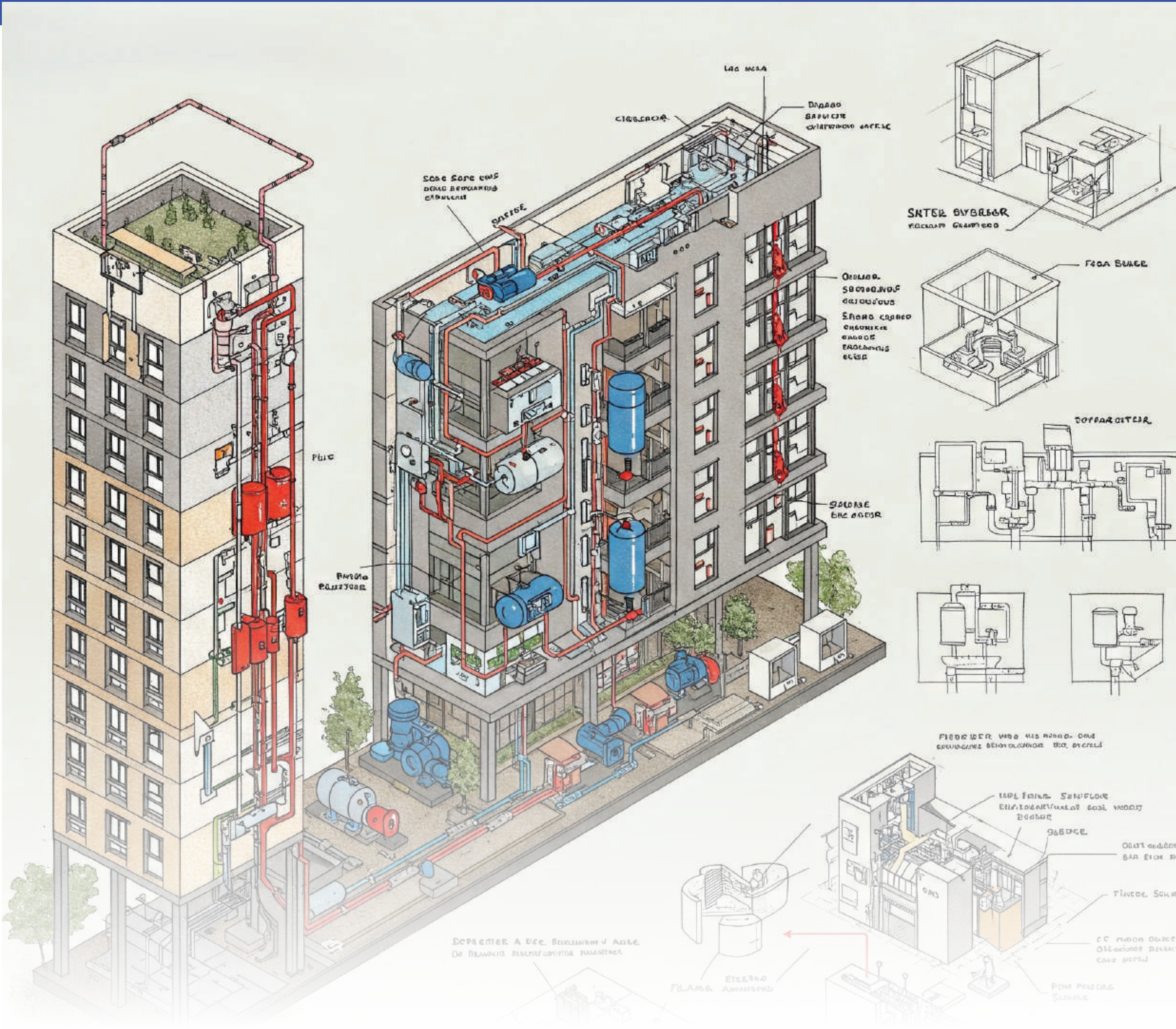

Domestic water system for High-rise Buildings (A case study)

By Syed Mubashir H. Kirmani

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Abstract

The primary objectives in the design of water supply system for High-rise Buildings are to ensure an adequate supply of water at the required pressure to all fixtures, outlets and equipment at all times and to achieve an economical, efficient and energy conserving installation.

Designing a domestic water system for a High-rise building, involves estimating water demand, utilizing pressure zones, employing booster pumps, and considering materials, all while adhering to local regulations and ensuring efficient water distribution .

Introduction:

A High-rise building is defined by 2015 International Building code as a building that is 75 feet taller or more. The reason behind the 75 ft. cutoff is that the Building code has specified fire protection requirements for fire and life safety as well as fire water service demands for buildings that meet or exceed this height.

- One of the eternal truths of life is that water is heavier than air. Water weight as 62.4 lbs. Per cubic feet at 68 degree F This mass requires a pressure of 0.433 psi to lift water one foot. To put it another way, one psi will raise water to 2.31 feet. If the basic facts about water characteristics are ignored in planning the water piping system of a High-rise building, we could have a disaster on our hands at the end of the construction.

The author has designed several High-rise building projects over the past four and a half decades and would like to share his experience with the readers, particularly with the Design Engineers.

Fundamental Requirements:

Providing domestic cold and hot water to the upper floors at required flow and residual pressure is a challenging job for the design engineer. The engineer must consider building height ,available municipal water pressure, pressure requirements not only at the upper floor but also throughout the building, flow demand, booster pump capacity and control, pipe and valve materials, riser location, pressure zones, pressure regulating stations, water heater storage capacity and recovery, water heater locations, domestic hot water circulations or using self-Regulating Stripp Heater, space requirements in building, economics, energy efficiency and acoustics.

The primary role of the design engineer is to determine the overall design solution that addresses the technical, physical and economic aspects of the project in compliance with the local code and meets or exceeds the client's expectations.

1. Domestic Water service Entrance Sizing and Devices:

Domestic water service is sized based on the absolute peak domestic flow rate (e.g., Hunter's Curve) of the building measured in gallons/minute (gpm).To find the domestic water peak flow rate for the building ,the designer would historically take the total number of plumbing Fixtures within the building that required potable water and convert fixture units value into gpm. However an increasing number of design professionals are now using the Water demand calculator (WDC) published by the International Association of Plumbing and Mechanical officials to estimate peak flow rate.

Once the total gpm for the building water supply has been determined the water service can be sized.

2. Domestic Water pressure:

Water pressure must be established for all points in the domestic cold and hot water system. The maximum pressure information at connection to the public mains and its consistent supply is the primary factor in sizing water booster pumps to serve the upper floor levels and to decide whether pressure reducing valves are required for the lower levels served directly by municipal pressure. To avoid the dangers attributable to excessive pressure some means must be provided to reduce the pressure to below the maximum of 70 psi . Pressure regulating valves(PRV) and vertical zoning have proven to be the best options of maintaining pressure within desired limit.(Plumbing code restrictions and ASPE Data Book recommendation limits the maximum water pressure at a plumb-(.ing fixture to 80 psi

3. Pressure losses

The third requirement is to account for pressure losses from the municipal water connection to the building's water supply system booster pumps, including premise isolation backflow prevention devices, water meters, strainers, valves and pipe losses.

4 Residual Water Pressure

The next requirement is to establish the residual water pressure required at the plumbing fixtures in the upper level of the project. Plumbing codes and the ASPE Data Book generally state the minimum water pressure at a fixture other than flush valve to be 15 psi or even less while the allowable maximum water pressure at a plumbing fixture is 80 psi. This pressure comes into the effect when we look at pressure zones within the building as later discussed.

5 Static Pressure

Static pressure is the largest component in most High-rise to be considered in design and is the water pressure that occurs based on the height of the piping system from the connection to the municipal water mains to the highest plumbing fixture, noting that there is a 0.433 psi static pressure change for each foot of elevation Chang.

6 Friction Lossess

The last pressure that needs to be calculated is the friction loss that results from water flowing through the piping system, which, pipe material roughness coefficient and viscosity.(However ,most pipe friction loss are based on potable water, therefore viscosity does not need to be adjusted.)

The pressure required to be generated by the domestic water booster pumps at the base of plumbing system now can be calculated as following:

Required pressure = Residual pressure at the highest fixture+Static pressure+Friction losses = Say X psi

If the minimum available pressure at the base of the system at the inlet to the pressure booster pumps is say Y psi, Then (X-Y) psi is the required capacity of the booster pump.

Zoning and PRVs:

Various schemes have been proposed and utilized throughout the years to minimize the number of PRVs. In recent years the method of zoning the building vertically and utilizing master PRV stations for each zone was introduced and has proven to be an outstanding success. By use of zones not only the number of PRVs is drastically reduced, but the design of hot water distribution system is greatly simplified.

Number of zones for any building can be determined as following:

Assume the pressure at fixture is to be 20 psi. In fact the type of water closet will determine the actual minimum pressure required. Pressure required for proper flushing of the water closet varies from 12 psi to 25 psi.

With the assumed 20 psi pressure, there is now an allowable additional pressure of 50 psi that can be accommodated before reaching the maximum pressure criteria of 70 psi. Fifty psi is equivalent to a static pressure of 50*2.31=115.5 ft. Now to obtain the maximum zone height, a down feed system is recommended so that gravity is working with the system instead of against it. With a PRV set for an outlet pressure of 20 psi the piping can now be rundown for 115.5 ft. before reaching 70 psi. If the floor to floor height is 12 ft. each zone can then be either 9 or 10 stories each noting that 115.5÷12 =9.6 . The top zone of any system would never require a PRV. If an up feed system is used for each zone, the PRV outlet pressure would be 0set at 70 psi.

Actual Installation (A Case Study)

A brief discussion of the domestic water system designed by the author for an 40 story office building has been built and has been operating satisfactorily. It would help the readers with the design principles of a High rise building.

1. Adopting a residual pressure at the highest Fixture in the building = 15.0 psi.
2. Keeping maximum pressure criteria = 70 psi.
3. Allowable additional pressure of 70-15 = 55 psi that can be accommodated before reaching the maximum pressure of 70 psi.
4. 55 psi = 55*2.31 = 127.05 ft

   To obtain the maximum zone height a down feed system should be employed, so that gravity is working with the system instead of against it. With a PRV set for an outlet pressure of 15 psi the piping can now be rundown for 127.0 ft before reaching 70 psi.
5. Floor to floor height = 12ft.

   Each zone can be (127.0 ÷ 12 = 10.58), 10 stories.

Possible options for cold water distribution systems are normally as following:

1. Direct Main supply water Distribution system: This system is possible when adequate pressure is available round the clock at the topmost floor through the city main water supply.
2. Direct Pumping Water Distribution system: With this System, water is pumped directly into distribution system without the aid of any overhead tank, except for flushing system.
3. Overhead Tank Water Distribution System: This system comprises pumping water to one or more overhead tanks placed at the top location of the hydraulic zone. The hydraulic zone or pressure zone refers to number of floors that can be served by the same pressurized stream of water. The overhead setup allows gravity to do the work of bringing the water down and ensuring sufficient pressure (Ref.1)
4. Hydro-pneumatic Water Distribution System: Hydro- pneumatic system is basically direct pumping system with the addition of a pressure pump and a pressure tank. The pressure tank is connected to an air compressor and to the distribution system. The addition of pressure tank helps to maintain water supply at the required flow and pressure round the clock. Water booster pump is operative only about 12 times per hour when pressure within the tank is insufficient to supply instantaneous water usage. This system conserves energy when water demands are low. This system is automatic but requires reliable power supply to avoid disruption in supply.
5. Combined Water Distribution System for High-Rise Buildings: It is also a general practice to use a combination of the system that we discussed above. The Arrangement and integration of these systems must be designed by taking into consideration the specific needs of the building. The above discussed factors should all be considered when understanding and designing plumbing system for High-rise buildings. (Ref.2)

Our Solution:

After careful analysis of all factors a reliable gravity system was selected with an 8000 gallon tank located at the top of the building, and a 12000 gallon tank located on the 20th floor.

Two pumps located at the lowest level to pump up water to the 20th floor tank. This tank serves as water supply for the 15th floor down to the lowest level and at the same time acts as a suction tank for the two pumps on the same 20th floor to pump water to the top tank. Capacity of the booster pumps:

1. **Capacity of Bosster pumps:** The rated capacity of the booster pumps at the lowest level is estimated as 300 gallons per minute at 240 Psi with due consideration of all possible eventualities. The estimated horse power of each pump is 55 H.P, while for the upper booster pumps capacity is estimated as 150 gpm at 120 Psi & rated horse power of each pump 15.0 HP. The arrangement of pumps installation at lower level is indicated in Fig. 03.

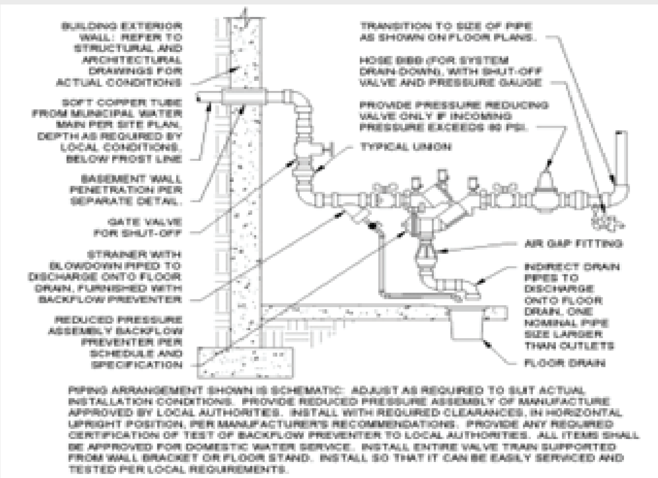

Figure No: 03

This tank supplies water for the 40th floor down to 15th floor, inclusive. The capacity of the two basement pumps is sized for the total building demand, whereas the capacity of the 20th floor pumps are sized only for the upper section of the building. Each pump is sized for the full load(some codes permit 2/3rd of the load for each pump) so that if one pump fails in the duplex setup the other pump is capable of keeping the system in operation.

By placing gravity tanks at the top and middle of the building, we have divided a building of its maximum height into two buildings approx. 240 ft each in height. One half of the building will now be discussed because the other half is designed identical. A main down feed riser runs from the tank down to the top of the lowest zone. For the 2nd zone below the tank the pressure will now be approx. 70 psi. For this and every zone below, the pressure must be reduced to 25 psi approx. so that it does not exceed 70 to psi at the base of each riser. PRV are utilized for this purpose.

After the PRV a connection is taken off for the water heater for that zone. System pressure at the heaters is always below 30 Psi, and the same is maintained for the hot water circulating pumps.

The beauty of this system is that no special material or extra heavy construction is required. The only piping in the entire installation that is subjected to pressures greater than 70 psi is the Pump discharge lines and main Risers from the tanks.

The hot water circulation system is also very economical and sustainable. From the heater a riser feeds down in the vertical bank of toilet rooms and at the base runs over to and up the other vertical of the toilet rooms, back to the heater for a closed loop. No additional circulating risers are required and there are no problems with balancing the system. Such an ideal set-up can probably be used for any office building. (See Fig.#1:Schematic flow diagram for cold water system; and Fig.# 2: Schematic Flow Diagram for cold and hot water supply for a Typical Zone).

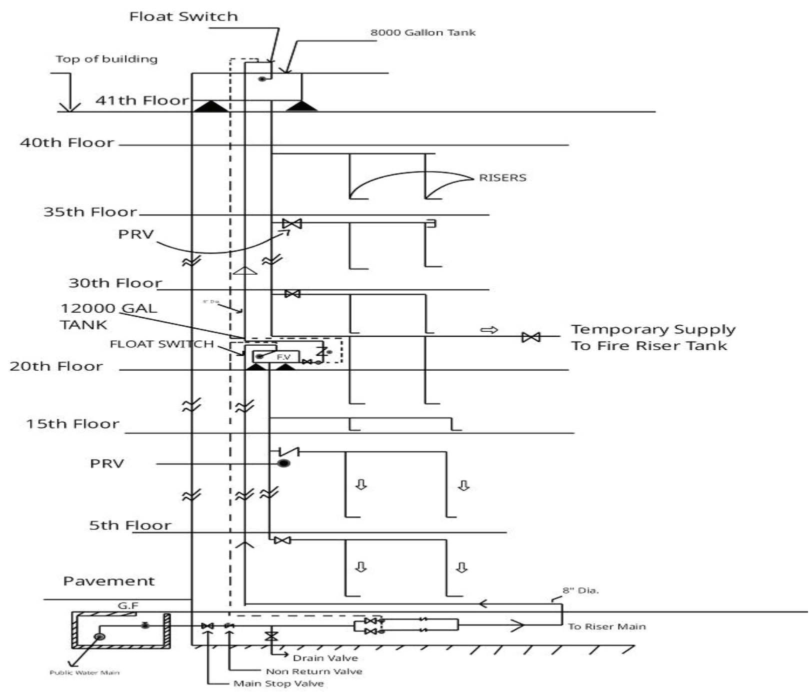

FIG. #1
(N.T.S)

Fig.1

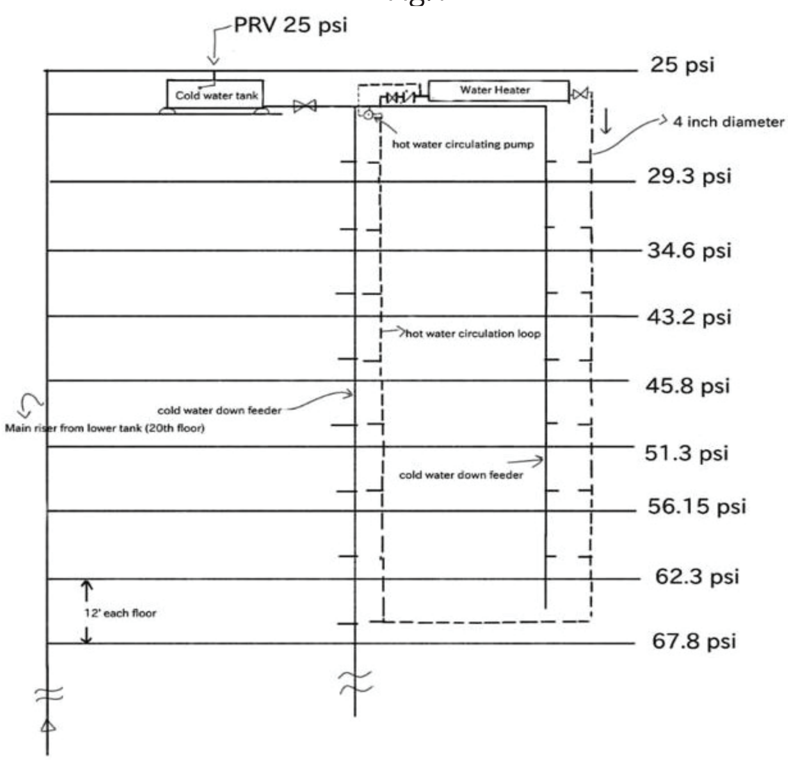

Fig. 2

(only pertinent features shown;
other required valves and piping deleted for clarity)

(N.T.S)

New innovation to replace hot water circulating system in a High-rise building:

Due to an exciting innovation, It is now possible to eliminate the requirement of separate water heater for each zone and specify a one-pipe hot water system with a central water heater for the total project, which requires absolutely no circulating system.

The installation of the self-Regulating heater on the hot water supply piping is very simple. The heater is run linearly on the pipe, for most zones and fastened with adhesive glass tape every 12 inches. Pipe insulation fits around the pipe and heater.(See Fig.04)

One end of the heater terminates inside a pipe -mounted junction box and the wiring from the junction box to the source of electricity. The other end of the heater is simply cut to length and terminated with an end seal. The parallel wire circuit design of the heater permits teeing-off to feed multiple risers from one base heater strip. A typical circuit can be a maximum of 475 feet in length.

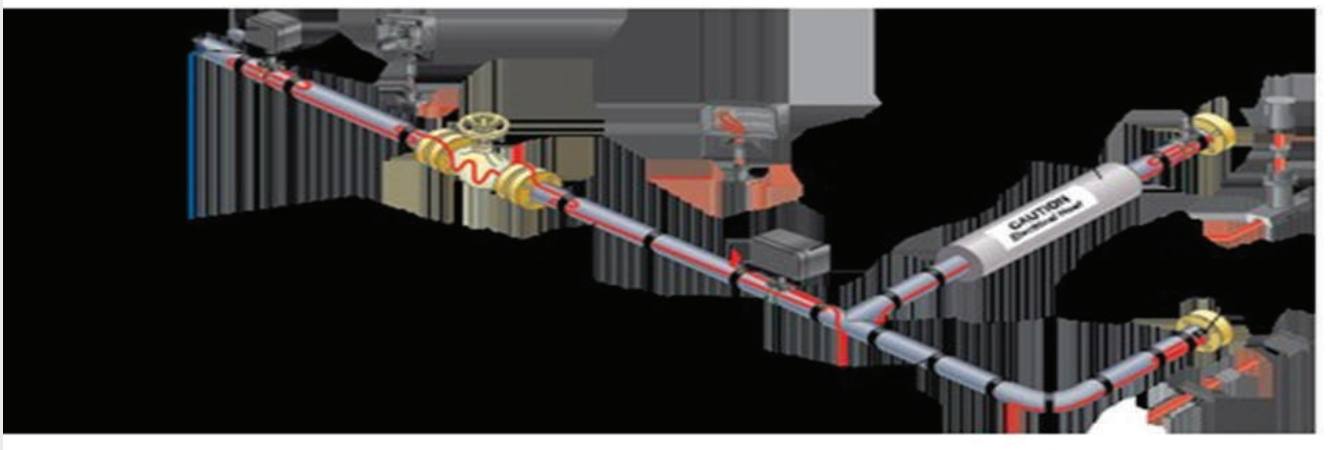

Fig No: 04

Comparison of one- pipe system versus two-pipe system of hot water:

It may be recalled that the conventional hot water system comprises of two- pipe System a water heater with storage tank, supply piping, circulating piping and circulation pump. Whereas the system utilizing the self - regulating strip heater is a one- pipe system of only one water heater tank , supply piping and self regulating strip heater. In one- pipe system the water heater (storage tank) is exactly the same as in two-pipe system and functions to bring the cold water supply to required system temperature. Controls for the heater are the same in both systems when the cold water has been brought up to the system temperature the self- regulating heater then maintains the water at this temperature throughout the supply piping. The self -regulating heater replaces the heat loss at the points along the supply piping where the heat loss occurs and since the water temperature is continuously maintained. There is no need for circulating piping, balancing valves, circulation pumps and controls.

Advantages of self-regulating heaters:

The advantages of the one-pipe system can be divided into four basic categories:

1. Lower installed cost.
2. Lower energy consumption.(Lower

operating cost.)

3. Easy system design.
4. Improved system performance.

The design engineers are obliged to implement the code requirements:

1. Electric Strip heating system are inherently less energy efficient than heat pumps as they directly convert electricity into heat.

2. There is a serious constraint to the complete acceptance of the self-regulating strip heater and eventually elimination of the circulation system by the codes. Every code specifically requires that hot water be circulated when the building is more than three stories in height or the run of supply piping exceeds 100 ft. It is important that until the code writing authorities give attention to the breakthrough of the self-regulating strip heater the design Engineers are obliged to the code requirements.

Conclusion:

All available options must be considered during the engineering of Domestic water systems for High-rise Buildings and many design solutions are available to the design Engineers as discussed above in the text. The water pressure vary at each level throughout the building and always must be considered in the system layout and when selecting equipment and piping material.

Energy efficiency, space requirements, economics and acoustics all play important roles in a successful project delivery to the client. In our case we have adopted a gravity tanks system. (12000 gallons tank located on the 20th.floor while a 8000 gallons tank was installed at top of the building. The beauty of this system is that no special materials or extra heavy construction is required.

The self -regulating strip heater concept is unique in that it offers both lower installed cost and lower operating cost. It is the advantage of these benefits that makes the one-pipe system such an attractive alternative to the conventional two-pipe hot water system. But the designer is obliged to comply with the code's requirements of a hot water circulation system.

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Developing and Implementing a Combined Assurance Framework for Large Energy Companies

By Mian Abdul Hamid

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Abstract

This research paper explores the development and implementation of a Combined Assurance Framework (CAF) tailored for large Energy companies, with a specific focus on enhancing risk oversight, governance efficiency, and strategic decision-making. The study proposes a blended framework that synthesizes internationally recognized standards and best practices, including the King IV Report on Corporate Governance, the COSO Enterprise Risk Management Framework, and ISO 31000 for Risk Management, and the Institute of Internal Auditors' (IIA) Three Lines Model.

The paper addresses the complexity of assurance functions across multiple departments such as

Enterprise Risk Management (ERM), Internal Control, Compliance, Business Continuity Management (BCM), Cybersecurity, Health, Safety & Environment (HSE), and Internal Audit. Through a structured methodology, it presents a step-by-step model for designing a unified assurance map, assurance scoring system, and reporting mechanisms aligned with Board of Directors (BoD) expectations.

A detailed case study of a large Energy utility company illustrates the framework's real-world implementation, integration with existing systems (e.g., Enablon), and the transition from silo assurance activities to a cohesive, automated approach. The case highlights challenges such as assurance overlap, data inconsistency, and cultural barriers, and demonstrates how these were addressed through a centralized governance model and risk taxonomy alignment.

The findings confirm that a well-integrated Combined Assurance Framework significantly improves assurance coverage, reduces duplication, and strengthens accountability across all lines of defense. The paper concludes with practical recommendations for Energy companies aiming to adopt a value-driven, technology-enabled combined assurance model.

1. Introduction

Combined assurance is an integrated approach to managing risks across multiple levels of an organization. It ensures that various assurance providers collaborate to cover all aspects of risk and control to give the , BoD, CEO, and stakeholders a clear, unified, and accurate view of whether key risks are being effectively managed and controlled across the organization.

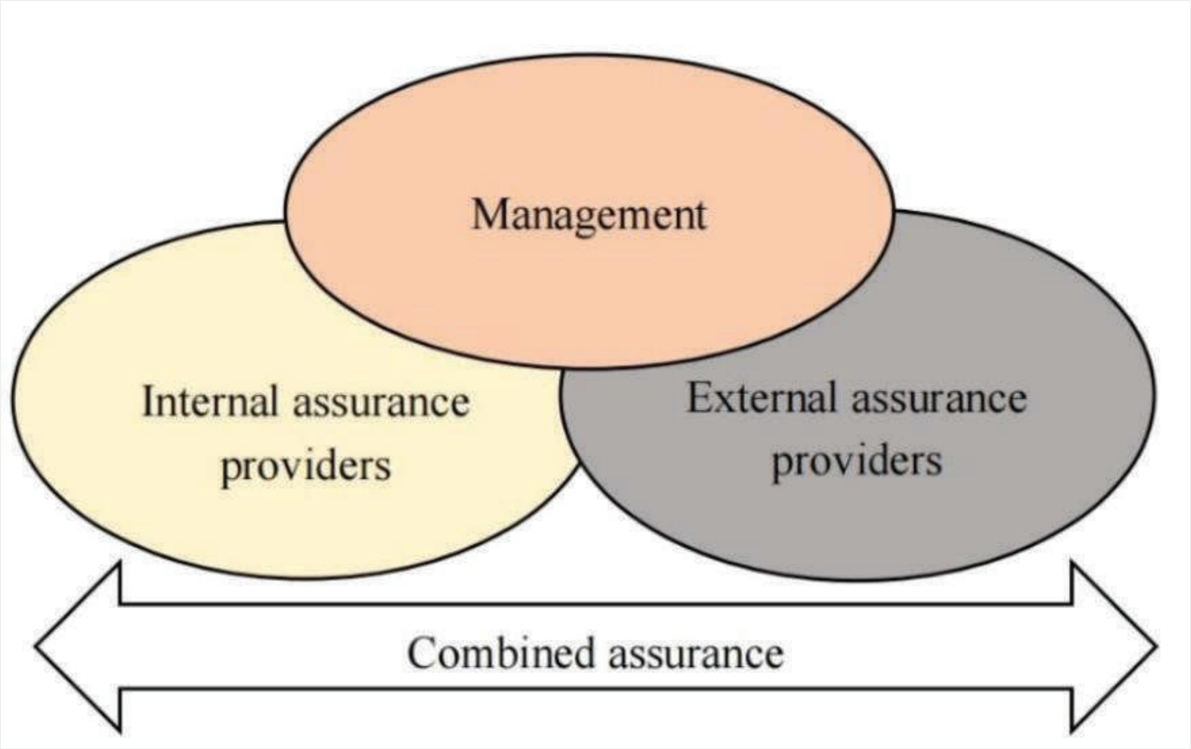
This is a structured, collaborative approach that aligns and integrates the activities of all assurance providers—such as internal audit, risk management, compliance, environmental, safety, cybersecurity, BCM, internal control, Quality Control, Quality assurance, legal, crisis management and operational teams—to deliver coordinated, efficient, and holistic assurance over the company's key risks, controls, and objectives.

In the context of a large Energy company, combined assurance ensures that critical risks—such as grid stability, regulatory compliance, asset integrity, cyber threats, environmental impact, and safety—are effectively managed and reported to senior leadership and the board, without unnecessary duplication of effort or gaps in oversight.

Why It Matters in an Energy Company:

1. **Operational Complexity**: Energy companies manage generation (e.g., coal, gas, nuclear, renewables), transmission, distribution, and customer interfaces—all with different risk profiles.
2. **High-Risk Environment**: Power outages, infrastructure failure, and safety incidents can have wide-reaching impacts.
3. **Heavily Regulated**: Must comply with national energy regulators, environmental laws, and cybersecurity standards (e.g., NERC CIP, ISO 27001).
4. **Sustainability Pressures**: Need strong assurance over ESG commitments, DE carbonization targets, and clean energy transitions.
5. **Innovation & Disruption**: As the company adopts smart grids, IoT, and digital technologies, assurance must also cover digital transformation risks

Picture-1:



2. Major Challenges in Creating a Combined Assurance Framework in Large Energy Companies

While many large Energy companies acknowledge the value of Combined Assurance, they still face significant barriers when trying to implement or mature it. Following are the major challenges.

2.1 Functional Silos and Lack of Integration

Problem: Departments like ERM, Internal Audit, Compliance, and Cybersecurity often operate in isolation. Cause of the problem might be absence of common risk language, reporting formats, or centralized GRC systems.

Impact: This leads to duplication of work, misaligned priorities, and fragmented risk reporting.

2.2 Unclear Roles and Responsibilities

·**Problem**: Overlaps (or confusion) between who owns a risk and who assures it. E.g. Internal Control and Internal Audit may both assess financial risks without clear boundaries. · **Impact**: Creates inefficiencies and accountability gaps.

2.3 Lack of a Formal Framework or Mandate

- **Problem**: Many companies have informal coordination but no documented Combined Assurance Framework or Board-approved charter.
- **Impact**: Leads to inconsistent application, lack of enforcement, and poor visibility to senior leadership.

2.4 Inconsistent Risk and Assurance Language

- **Problem**: Risk terminology and scoring systems vary across departments. E.g. "Critical" in Cybersecurity may not mean the same as "High" in ERM.
- **Impact**: Difficult to aggregate and report risks meaningfully to the Board.

2.5 Lack of Technological Integration

- **Problem**: Assurance activities are often managed in disparate systems (Excel, local databases, and different tools).
- **Impact**: Real-time consolidation of assurance data is hard, and reporting becomes manual and error-prone.

2.6 Cultural Resistance and Turf Protection

- **Problem**: Some departments may fear loss of autonomy, visibility, or influence. Legacy hierarchies, control-oriented mindsets.
- **Impact**: They may resist centralized coordination or fear transparency will expose weaknesses.

2.7 Board and Executive Engagement Gaps

- **Problem**: Senior leaders may not fully understand the value or structure of Combined Assurance.
- **Impact**: Lack of top-down sponsorship delays implementation or underfunds the function.

2.8 Regulatory Complexity and Changing Compliance Environment

- **Problem**: Especially in regions like Saudi Arabia, large energy companies face evolving laws (e.g., cybersecurity, ESG, NCA, etc.).
- **Impact**: Hard to coordinate assurance when new regulations continuously shift departmental priorities.

2.9 Insufficient Data Analytics and

Assurance Mapping Tools

- **Problem**: Companies often lack risk intelligence tools to automate assurance mapping, visualize coverage, and detect gaps.
- **Impact**: Manual mapping becomes outdated and ineffective, especially in large asset-heavy companies.

2.10 Failure to Measure Assurance Effectiveness

- **Problem**: Few companies have KPIs or performance metrics to track the efficiency and coverage of their assurance functions.
- **Impact**: Hard to show ROI or make a business case for investing in GRC tools and integration.
- To overcome these, companies should adopt a formal Combined Assurance Framework. In next section we will provide the commonly adapted standards and best practices followed by developing a robust blended combined assurance framework based upon King IV**,** ISO 31000**,** COSO**,** and IIA's Three Lines Model.

3 Commonly used Combined Assurance Frameworks

The **King IV Report on Corporate Governance**, **ISO 31000**, **COSO**, and **IIA's Three Lines Model** are foundational frameworks for combined assurance. These models help organizations structure their risk management activities and ensure alignment with best practices in governance.

- **King IV Report**: Focuses on ensuring ethical leadership, responsible risk management, and strategic decision-making.
- **ISO 31000**: Provides guidelines for integrating risk management into the organizational culture.
- **COSO**: Offers a risk management framework that supports the alignment of controls with business objectives. · **IIA's Three Lines Model**: Divides risk management responsibilities into three lines:

operational management (Line 1), risk management and compliance (Line 2), and independent assurance providers (Line 3).

4 Developing a blended robust combined assurance model:

4.1 Blending Approach for Combined Assurance Model:

Incorporating **a** blended app4.1 roach for combined assurance in a large Energy company requires integrating elements from **King IV**, **ISO 31000**, **COSO**, and **IIA's Three Lines Model**. This tailored approach will ensure that all aspects of risk, governance, and assurance are effectively covered, while also respecting country's regulatory landscape and industry-specific requirements.
Here's how each framework can contribute to building a :robust combined assurance model

4.1.1 King IV: Governance and Assurance Coordination

Core Focus Area: Integrated Governance, Assurance, and Risk Management

- **Primary Application in Energy Company**: King IV promotes a **coordinated approach** to assurance, and its principles can be adapted to address the complex nature of the Energy sector. Energy companies are heavily regulated, with high expectations for governance, safety, compliance, and sustainability.

- **Combined Assurance Forum**: King IV emphasizes creating a **formal combined assurance forum**, where all assurance providers (e.g., internal audit, risk management, compliance, HSE, cybersecurity) meet regularly to share risk insights, identify gaps, and collaborate.
- **Governance Oversight**: King IV encourages the **board** to have oversight of assurance activities, ensuring that all key risks (e.g., grid reliability, cyber threats, regulatory compliance, and ESG obligations) are covered and aligned with business objectives.
- **Practical Example:** For a large Energy company, the **Combined Assurance Forum** would meet quarterly to review the effectiveness of assurance efforts across critical areas like **grid security**, **cybersecurity**, **HSE standards**, and **regulatory compliance**. The board would get a consolidated report on **key risks** and **assurance coverage**, aligned with their strategic objectives.

4.1.2 ISO 31000: Risk Management

Core Focus: Risk Management Framework and Integration

- **Primary Application in Energy Company**: ISO 31000 provides global best practices in risk management and can help structure the organization's approach to identifying, assessing, and treating risks across the Energy value chain (generation, transmission, distribution).
- **Risk Integration across Functions**: ISO 31000 encourages integrating risk management into the organization's culture and processes. In Saudi Arabia's Energy sector, this is especially relevant given the need to manage environmental risks, grid stability, and regulatory compliance.
- **Stakeholder Communication**: The standard advocates for clear communication of risks to stakeholders—critical in an industry that deals with national infrastructure.
- **Practical Example**: ISO 31000 would guide the creation of risk registers for critical risks like power generation reliability**,** cybersecurity threats, and compliance with local and international regulations**.** Risk management would be embedded in the company's decision-making process, with a centralized GRC system used to assess, track, and report on key risks.

4.1.3 COSO ERM Framework

Core Focus: Enterprise Risk Management (ERM) and Internal Control

- **Primary Application in Energy Company**: COSO's ERM Framework focuses on aligning risk management with strategic objectives and ensuring that internal controls are robust and efficient. This framework is crucial in sectors like energy, where risks span from operational to financial, and regulatory and environmental concerns are pressing.
- **Strategic Alignment**: COSO's ERM helps align risk management with the company's strategic objectives. For a large Energy company, this can help ensure that risks related to grid stability, energy transition, and sustainability goals are prioritized alongside financial performance.
- **Internal Controls**: COSO emphasizes creating strong internal controls, which are crucial for safeguarding against risks like financial fraud, operational failures, and regulatory breaches.
- **Risk Appetite and Tolerance**: COSO provides guidance on establishing risk appetite—useful for balancing operational risks, such as plant failures or natural

disasters, with acceptable levels of risk.

- **Practical Example**: COSO's ERM Framework would help an Energy company clearly define risk appetite related to critical infrastructure and align it with the company's objectives to achieve sustainability goals and regulatory compliance. The internal controls system would be strengthened to ensure operational resilience and financial accuracy.

4.1.4 IIA's Three Lines Model

Core Focus: Assurance Roles across the Organization

- **Primary Application in Energy Company**: The Three Lines Model ensures that assurance roles are clearly defined and coordinated across the organization, minimizing duplication and improving overall risk management effectiveness.
- **First Line (Management Controls)**: Operational management in charge of day-to-day risk management and control implementation across generation plants, grid operations, and customer service.
- **Second Line (Risk, Compliance, and HSE)**: Specialized teams like risk management, compliance, health, safety & environment, and cybersecurity that provide guidance and oversight to management, ensuring that policies and risk controls are followed.
- **Third Line (Internal Audit)**: Internal audit provides independent assurance, assessing the effectiveness of the first and second lines of defense and reporting findings to the board. · **Practical Example**:

- The **first line** (management) will implement operational controls such as maintenance schedules, cybersecurity protocols, and ESG reporting.
- The **second line** (risk, compliance, and HSE) will provide oversight, ensuring regulatory compliance with local authorities (e.g., Saudi Energy Efficiency Program), risk assessments, and environmental regulations.
- The **third line** (internal audit) will assess the overall effectiveness of risk controls, performing audits on processes like asset management, grid reliability, and cybersecurity defense mechanisms.

4.2 Robust Combined Assurance Model for Energy Company:

The best blend of combined assurance in a large Energy companies would involve harmonizing the King IV model for governance with ISO 31000's integrated risk management**,** COSO's strategic risk alignment, and the IIA's Three Lines to ensure effective coverage of all critical risks. This holistic approach will provide the company with a robust, transparent, and efficient assurance model that meets local regulatory requirements, aligns with global best practices, and ensures operational, regulatory, and financial resilience**.**

4.2.1 Governance and Oversight (King IV):

- Create a **Combined Assurance Forum** that coordinates the assurance providers (internal audit, risk management, HSE, IT security, compliance).
- Ensure that the **board** receives regular integrated reports that include both strategic and operational risks (e.g., grid failures, compliance, cyber threats).

4.2.2 Risk Management Framework (ISO 31000):

- Integrate **risk management** into the company's culture, with a **centralized risk register** tracking major risks like

regulatory compliance, **environmental risks**, and **operational risks** (e.g., aging infrastructure).

- Use **shared platforms** (e.g., GRC software) to monitor, assess, and mitigate risks.

4.2.3 Internal Controls and Strategic Alignment (COSO ERM):

- Align **internal controls** and **risk management** with **strategic objectives**, especially focusing on critical risks like **energy transition**, **ESG goals**, and **national grid stability**. ○ Develop a clear **risk appetite** for key operational areas (e.g., energy production, transmission stability).

4.2.4 Clear Assurance Roles (IIA's Three Lines Model):

- Clearly define and align the roles of the **first line (management)**, **second line (specialized teams)**, and **third line (internal audit)**.
- Use the Three Lines to ensure that all assurance efforts are **coordinated** and **focused on critical risk areas** like **cybersecurity**, **safety**, and **compliance**.

4.3 Combined Assurance Structure and Lines of Defense

The **Three Lines of Defense Model** is widely used to structure combined assurance activities:

4.3.1 Line 1: Operational Management (Risk Owners)

- Responsibility: Day-to-day risk management and implementation of control measures. ○ Examples: Grid stability, plant operations, asset management, safety protocols.

4.3.2 Line 2: Risk & Compliance Functions

- Responsibility: Risk assessment, regulatory compliance, and monitoring. ○ Examples: Compliance with environmental standards, risk frameworks, and operational oversight.

4.3.3 Line 3: Independent Assurance Providers

- Responsibility: Independent assessment and audit of risk management effectiveness. ○ Examples: Internal audit, external audits, regulatory reviews.

4.4 Best Practices for Combined Assurance in the Energy Sector

4.4.1 Collaboration across Lines of Defense:

Effective combined assurance requires coordination between operational management, risk management, and independent assurance providers.

- **4.4.2 Regular Monitoring and Reporting:** Periodic assurance reports to the BoD should cover operational, strategic, financial, and compliance risks. These reports should offer transparency on how risks are managed and whether assurance activities are effective.
- **4.4.3 Integration of Technology:** Advanced tools such as Governance, Risk, and Compliance (GRC) platforms, AI, and data analytics can help improve risk assessment, reporting, and decision-making.
- **4.4.4 Continuous Improvement:** Assurance frameworks should be regularly updated to reflect changes in the regulatory environment, technological advancements, and emerging risks.

4.5 Challenges in Implementing

Combined Assurance in the Energy Sector

- **4.5.1 Complexity of Operations:** The vast scope of operations and the interdependence between different departments (e.g., generation, distribution, maintenance) complicates risk management efforts.
- **4.5.2 Regulatory Changes:** The dynamic nature of the regulatory landscape and international standards requires continuous adaptation of risk management strategies.
- **4.5.3 Technological Advancements:** Rapid technological changes (e.g., renewable energy, smart grids) require ongoing adjustments to risk management processes.

4.6 Conclusion

Combined assurance is critical for ensuring that large Energy companies, effectively manage enterprise risks and comply with regulatory requirements. By integrating multiple lines of defense and aligning with global standards like King IV, ISO 31000, and COSO, these companies can provide the Board of Directors with comprehensive assurance that the organization is managing risks appropriately. The implementation of combined assurance ultimately enhances governance, improves risk management, and supports strategic objectives in the dynamic energy sector.

5 Case Study: Operationalization of Combined Assurance in a Large Energy Company

In a large Energy company, where operational complexity and regulatory scrutiny are high, combined assurance provides a structured and integrated approach to managing enterprise risks. This section presents a practical example of how combined assurance functions within such an organization, focusing on a critical risk: widespread grid failure. The scenario demonstrates how various assurance providers coordinate to deliver efficient, comprehensive oversight and risk mitigation.

5.1 Scenario Overview: Grid Failure Risk

Consider a national Energy provider responsible for generation, transmission, and distribution of Energy across multiple regions. One of its key enterprise risks is "**widespread grid failure**," potentially caused by aging infrastructure, cyberattacks on operational technology (OT), or extreme weather events. Given the potential for widespread service disruptions and regulatory consequences, this risk is prioritized at the board level.

5.2 Step-by-Step Operation of Combined Assurance

5.2.1 Risk Identification and Collaboration

The risk management team (second line) identifies and records "Grid Failure" as a top-tier risk in the enterprise risk register. A cross-functional **Combined Assurance Forum** is then convened, involving internal audit, cybersecurity, health and safety (HSE), compliance, engineering, and environmental teams. The group agrees on a shared understanding of the risk and the need for collaborative oversight.

5.2.2 Integrated Assurance Planning

Each assurance function outlines their planned activities related to the grid failure risk:

Table-1:

Function	Assurance Activity
Internal Audit	Infrastructure readiness and control audits

Cybersecurity	SCADA system penetration testing
HSE	Field inspections at critical substations
Compliance	Grid code and regulatory compliance review
Environmental/ESG	Climate resilience assessment of transmission assets

These activities are consolidated into a **Combined Assurance Plan**, ensuring alignment of efforts and eliminating overlap.

5.2.3. Execution and Evidence Sharing

Assurance providers execute their assigned tasks independently but upload findings into a shared Governance, Risk and Compliance (GRC) platform**.** For instance:

The cybersecurity team identifies vulnerabilities in control systems.

- Internal audit uncovers delays in critical maintenance.
- HSE reports safety non-compliance at transformer stations.
- Environmental specialists highlight flood risk zones near major substations.

Each issue is linked to the common risk category, ensuring traceability and cross-functional awareness**.**

5.2.4 Integrated Reporting to Executive Leadership

The Combined Assurance Office consolidates findings into a single report and dashboard. It summarizes:

- The current risk status
- Key assurance activities completed
- Unresolved gaps
- Suggested mitigation actions

Table-2:

Risk: Grid Status Assurance Sources Gaps Identified Failure

High (Red) ⚑	Internal Audit, Cybersecurity, HSE,	SCADA vulnerabilities, flood risks,
	ESG, Compliance	maintenance delays

This report is submitted quarterly to the executive team and board-level Audit and Risk Committee, providing a **holistic view of assurance coverage** and facilitating informed decision-making.

5.2.5. Follow-up and Monitoring

Action plans are developed collaboratively and monitored for progress. For example:

- IT security implements immediate patches for SCADA vulnerabilities.
- Operations prioritize substation upgrades in high-risk flood zones. · Maintenance backlogs are addressed using reallocated resources.
- Progress is reviewed during the next combined assurance cycle, with continuous feedback loops enhancing learning and agility.

5.3 Key Outcomes and Value Realized

The implementation of combined assurance in this scenario yields several organizational benefits as below:

- **Efficient Resource Use**: Duplication is avoided, freeing up time and reducing costs.
- **Enhanced Collaboration**: Teams work in synergy rather than silos.
- **Improved Risk Coverage**: All aspects of a complex risk are addressed comprehensively.
- **Board-Level Clarity**: Leadership receives concise, integrated reports for better governance.
- **Regulatory Readiness**: The organization demonstrates strong assurance and risk governance to regulators.

This practical example demonstrates how combined assurance, when applied effectively, transforms a traditionally fragmented assurance landscape into a **unified, strategic governance tool**. In high-stakes industries like Energy, where reliability and compliance are paramount, this model not only enhances risk management but also strengthens the company's resilience and long-term sustainability.

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Federated Learning for Network Intrusion Detection: A Collaborative Approach

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Abstract—An intrusion encompasses any event that may damage information concerning its availability, integrity, or confidentiality. An Intrusion Detection System (IDS) not only identifies such hazards but also provides a multi-faceted series of response options that are intricately tailored to different organizational requirements and attack types. Developing machine learning models for intrusion detection systems often struggles dealing with large multi-label, multi-dimensional datasets. The diversity of traffic patterns within a given network makes the performance of IDS less efficient in real-world applications. Dynamic, situation-aware, and time-critical applications can potentially benefit from Federated Learning by ensuring privacy in data, intelligent and active responses, adaptable action, and efficient, scalable, and high-performance communication.

Index Terms—Deep Learning, Federated Learning, Intrusion Detection System, Machine Learning

Introduction

Information systems have boundaries or parameters that, when intentionally crossed, enable potential damage to be inflicted termed as an intrusion. It includes carrying out actions that result in restricting access to computer services for authorized users. An Intrusion Detection System (IDS) is a tool in the form of software or hardware, that helps in monitoring the system security of a network to detect, and identify, hostile activities directed towards it [1]. IDSs are supposed to safeguard systems where traditional firewalls overlook some types of hazardous network traffic or computer activities. Audio and video surveillance can be effective in restricting breaches in the availability, integrity, and confidentiality of computer systems. Research shows a notable amount of concern in coming up with secure systems through effective and efficient intrusion detection.

Two main strategies define the way an IDS is built: Signature-based Intrusion Detection Systems (SIDS), and Anomaly-based Intrusion Detection Systems (AIDS) [2]. SIDS depends on pattern-matching techniques to identify attacks. In this method, a database of known malicious activity patterns is created. The system scans available activity logs and compares them with recorded patterns; if a match is found, an alert is activated [3]. This type of technique is also called Knowledge-Based Detection or Misuse Detection in the literature. While SIDS can detect known attacks with high accuracy, they tend to be less effective at identifying new attacks, also known as zero-day attacks. The reason for this is that there is no corresponding signature available in the database until the attack pattern is discovered and stored [4].

AIDS gained a great deal of popularity because of how easily they adapt to the shortcomings of SIDS. As for AIDS, an anomaly is characterized as any large difference between the behavior that is observed and the model that is expected, which is considered an auto intrusion. AIDS uses Machine Learning (ML), statistical models, and knowledge-based techniques to establish a baseline of normal system behavior [5]. AIDS is very proficient in detecting zero-day attacks by issuing alerts based on the absence of activity relative to established patterns. One of the key strengths of AIDS is its ability to identify internal threats. For example, AIDS sets off an alarm when an illegitimate user accesses an account and performs transactions that are not characteristic of the activity of the account holder [6]. Moreover, AIDS can observe attention when an unauthorized user takes on the identity of a legitimate user and executes transactions that are atypical for that specific system [7]. A general overview of an IDS is depicted in Figure 1.

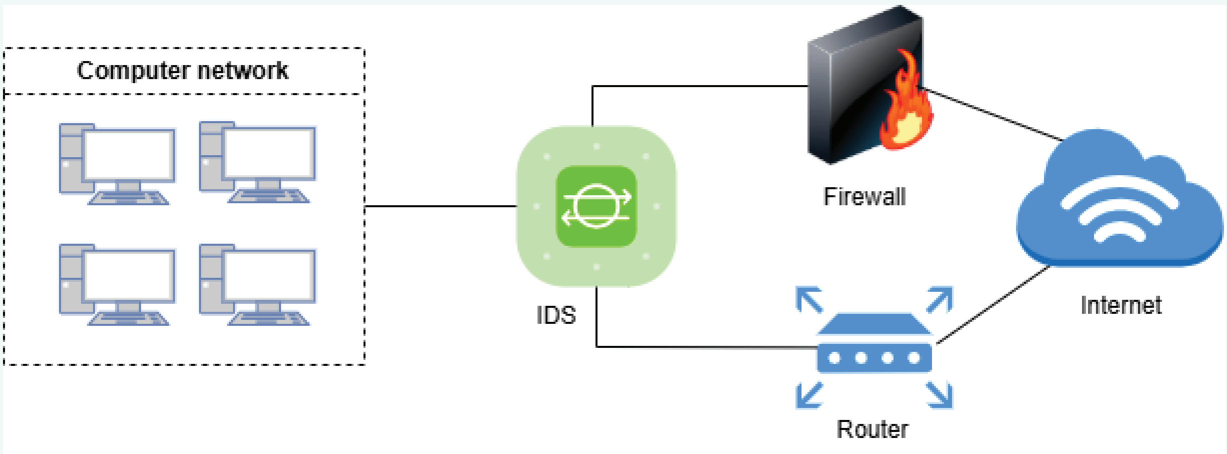

Fig.1: Intrusion Detection System

This paper discusses the application of Federated Learning (FL) to IDS. It analyzes ML and deep learning (DL) approaches for intrusion detection and discusses challenges related to FL. Sections 2 and 3 focus on methods of intrusion detection based on ML and DL, while sections 4 and 5 discuss the fundamental principles of FL, its architecture, its possible use with IDSs, and its future developments. Section 6 concludes the paper.

2. Machine Learning based Intrusion Detection

ML-based approaches focus on building a system that learns from provided data and recognizes patterns to classify new or unknown inputs. An IDS can be defined as a system that classifies and predicts network attacks using a representative dataset. Data collection includes the aspects of gathering network data, while data pre-processing deals with converting the collected data into a more appropriate structure for analysis.

Constructing an ML model is generally considered to be comprised of four major processes. Feature Engineering entails the feature selection and extraction processes which may minimize the dataset's size and highlight particular attributes, thus reducing the cost of computation [8], [9]. The classification stage comprises implementing the chosen ML algorithm to the data and searching for identifiable patterns to make predictions. In ML-based IDS, the first three steps are learning normal behavior, data classification, and performance evaluation based on predefined metrics [10]. ML models monitor and recognize intrusions via an automated learning process that utilizes patterns derived from network characteristics obtained from network packets. An ML model scans the network data for specific patterns or signatures and attempts to match them to known malicious patterns. If the incoming signature matches some captured vulnerability's signature, it is considered abnormal [11]. The most frequently used techniques in ML-based IDSs are Support Vector Machines (SVM), k-Nearest Neighbor (k-NN), Random Forest (RF), Naive Bayes (NB), Decision Tree (DT), and clustering techniques [12]. These techniques are systematically evaluated in Table 1 for their merits and drawbacks.

Table 1: Advantages and disadvantages of machine learning algorithms in IDS

Algorithm	Description	Advantages	Disadvantages
Logistic Regression	Estimates the probability of a binary outcome (e.g., intrusion vs. non-intrusion) based on input features	Simple and easy to interpret, suitable for binary classification, provides probability estimates	Assumes linear relationship between predictors and outcome, limited capacity for capturing complex patterns
Decision Trees	Constructs a tree structure to classify instances based on attribute values	Easy to interpret and visualize, handles both numerical and categorical data, performs implicit feature selection	Prone to overfitting with deep trees, sensitive to small variations in data
Random Forest	Ensemble method using multiple decision trees for classification	Reduces overfitting compared to single trees, provides feature importance, handles large datasets well	Computationally expensive, less interpretable compared to single decision trees
Support Vector Machine ((SVM	Creates a hyperplane to separate different classes in a high-dimensional space	Effective in high-dimensional spaces, handles non-linear decision boundaries using kernel tricks, works well with small to medium-sized datasets	Memory-intensive for large datasets, choosing the right kernel and parameters is challenging
k-Nearest Neighbors ((kNN	Classifies instances based on the majority class of nearest neighbors	Simple and intuitive, no training phase required, robust to noisy data	Computationally expensive during testing, sensitive to irrelevant and redundant features

3. Deep Learning based Intrusion Detection

DL is considered a specific type of ML that employs artificial neural networks (ANNs), which are designed to mimic the structure and operation of biological brains. The difference that distinguishes DL architectures from other ML approaches is the presence of several layers within the network [13], [14]. Several DL techniques are identified in the literature, for example, long short-term memory (LSTM), deep neural networks (DNNs), convolutional neural networks (CNN), generative adversarial networks (GANs), and recently, Generative Pretrained Transformers (GPT) [15]. An overview of ML and DL-based approaches is presented in Figure 2.

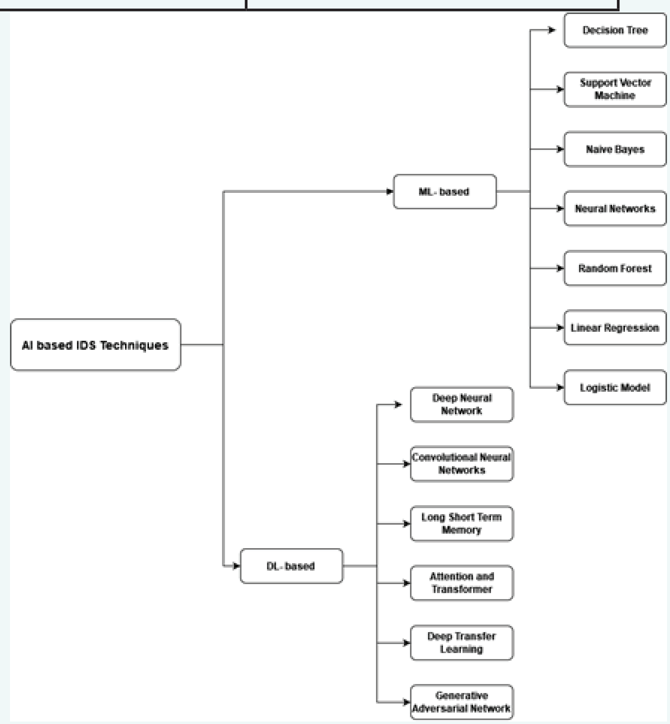

Fig.2: Overview of ML and DL techniques for IDS

Research indicates that after completing the training, the model is evaluated against a different dataset to determine its effectiveness [16]. When the model meets the expected performance criteria, the IDS can be considered to have been deployed in monitoring mode. If the model fails to meet these criteria, however, the algorithm is retrained using new data. During this monitoring stage, the IDS takes control of network communication and analyzes the traffic for activity, utilizing an algorithm to identify unusual traffic patterns. In cases where the IDS identifies abnormal patterns, it will notify the operator with a warning. However, in most cases, the system continues observing [17]. Despite these strategies, ML and DL have stood out in solving problems; however, they still suffer from these challenges:

1. To train the model, users' private data needs to be relayed to a central broker which could breach confidentiality.
2. With a larger network size, performance continues to increase as a single point of failure which could risk system integrity and Quality of Service (QoS).

3) A determined amount of time is needed for the fast analysis of data by the IDS, but centralized processing could cause delays and inefficiencies.

Compared to DL solutions for intrusion detection, traditional approaches, including ML techniques, are more straightforward and less resource-demanding. However, the main obstacle to deploying DL algorithms is their extensive requirement for CPU, memory, and other resources, especially in cases where these components are scarce [18]. Moreover, to function adequately, DL models need abundant training data [15]. The benefits and drawbacks of these approaches are presented in Table 2. Sufficient datasets are hard to collect, due to the sensitive nature of the relevant data, which makes availability a challenge.

Table 2: Advantages and disadvantages of deep learning algorithms in IDS

Algorithm	Description	Advantages	Disadvantages
Convolutional Neural Networks (CNNs)	CNNs are highly effective for image classification tasks and can process packet payloads or network .traffic data represented as images	Automate feature extraction, handle spatial relationships effectively	Require large, labeled datasets, computationally intensive
Recurrent Neural Networks (RNNs)	RNNs capture temporal dependencies in network traffic data, en-.abling pattern detection over time	Effective for sequential data analysis, capable of learning temporal patterns	Susceptible to vanishing and exploding gradients, prone to overfitting without regularization
Long Short-Term Memory Networks (LSTMs)	LSTMs are designed to address the vanishing gradient problem in RNNs, making them suitable for .long-range dependency learning	Efficient for learning long-term dependencies in sequences	Complex architecture, computationally expensive, slower training
Autoencoders	Autoencoders reconstruct normal data and identify anomalies by detecting deviations from expected .patterns	Unsupervised approach for anomaly detection	Requires a large volume of normal data for effective training
Deep Reinforcement Learning (DRL)	DRL integrates deep learning with reinforcement learning to optimize decision-making in sequential .tasks	Adaptive and dynamic response to evolving threats	Requires complex tuning of reward functions and exploration-exploitation balance
Generative Adversarial Networks (GANs)	GANs generate synthetic network traffic data for dataset augmentation and detecting adversarial .attacks	Enhance data diversity through synthetic data generation	Training instability and mode collapse

Federated Learning (FL) can solve a myriad of problems. FL can be applied to extremely sensitive, real-time tasks with the needed levels of autonomy and privacy. The network can achieve scalable solutions with low latency and energy-efficient communication with successful implementation of FL. These attributes allow more effective implementation of machine learning and deep learning in intrusion detection systems, thus improving their performance.

4. Federated Learning

Google developed Federated Learning (FL) in 2016 to allow Android users to update models from their devices without violating personal data privacy. Subsequently, Google created an FL framework tailored for mobile devices to run the FedAvg algorithm [19]. This framework enables federated data analytics and can collect statistics from several big clusters without saving raw data from devices in the cloud. FL has since become established as a central approach within the context of privacy-sensitive computing [20]. The lightweight FL framework and ease of deployment made it the solution of choice for several implementations with heightened sensitivity to privacy [21]. With the development of FL technology, research activity in this field has also increased enormously. FL acts as a federated form of a machine learning system where the execution of algorithms happens in parallel across multiple distributed nodes or edge servers while ensuring that the sensitive data remains stored locally and is never exposed outside the perimeter [22], [23].

In FL, local clients, rather than centralized organizations, manage data training [24]. The communication between the client and server is parameter-based, so no actual data is transferred. The server performs parameter aggregation to update the global model, which shifts the processing and storage burden from the server while ensuring that the user data remains protected [25]. This enables FL to feature a globally optimized model through client-server communication that is decentralized [26].

Architecture of FL

FL enables the development of powerful models using decentralized and private data while preserving individual privacy, making it a pioneering approach to collaborative machine learning [27]. The architecture of deployment as well as the type of selected IDS greatly influence the effectiveness of an IDS. Depending on the specific requirements of the system, there are three main strategies to deploy an IDS: centralized, decentralized, and distributed.

Centralized deployment of an IDS is best suited for smaller networks that have low scalability. This form of deployment relies on centralized IDS, which must be fed data to train the ML model built into the IDS [28]. Clients holding local datasets and possessing some computing power become crucial in this system. The clients construct local models and subsequently report the most recent learned data (model updates) to a central coordinator. The coordinator uses privacy-preserving methods to aggregate these updates, subsequently sharing the global model and supervising the training process [19]. There is a need for robust, secure communication protocols to protect the privacy and integrity of the data during transmission. Safeguarding the individual's information throughout the training stage could be one of the main issues. Certain techniques like differential privacy and secure aggregation introduce artificial noise or use cryptographic techniques to safeguard the private information of each client while still achieving reasonable accuracy for the model [29].

Moreover, the architecture can be improved with features such as those that provide incentives to guarantee the participation of clients and federated meta-learning that seeks to promote faster training by allowing clients to share learning outcomes [30]. The architecture is defined according to privacy needs, data dissemination, and particular scenarios along with communication, centralization, and privacy-security trade-off efficiency.

FL-based Intrusion Detection

Anomaly-based Intrusion Detection Systems (AIDS) tend to issue a large number of false alerts due to reasons like unlabeled and missing datasets, along with poor algorithms. Hackers can change the way they try to intrude in order to get past IDS using methods such as traffic masking and network steganography, among other evasion techniques [31]. To establish an IDS with low false alarms and high detection accuracy, suitable hardware must be available. The presence of greater complexity and the need to detect advanced attempts of intrusion makes effective detection and response systems, as well as IDS training particularly challenging when using small, homogeneous global datasets. While richer data is beneficial, the performance of distributed IDS remains constrained by the low data volume [32]. FL provides a means of addressing the concern of insufficient data. FL permits multiple devices to collaboratively train a model without compromising sensitive, raw data. For example, in the case of intrusion detection, FL allows independent analysis of local network traffic by network devices, which works towards enhancing the collective intelligence of the intrusion detection system. Rather than sending the raw data back to a central server, FL processes the data by training the model locally on every device and only sending back the model's updated weights. This provides the opportunity to collect real-time data from client devices, which can mitigate the network security issue. A more extensive data pool from a larger network can help improve client network defense. Nonetheless, some difficulties arise with implementing FL.

How FL Can Enhance IDS?

FL makes several improvements to intrusion detection systems, overcoming the weaknesses of classical techniques. Initially, it improves the confidentiality and integrity of IDS by ensuring that sensitive data stays within the local network. With raw data being stored on separate devices, FL minimizes the chances of data leaks and access to confidential information. Table 3 presents the summary of approaches and challenges of intrusion detection while using FL.

FL also enhances the scalability of IDS. FL can manage huge amounts of network traffic without crashing a central server by distributing its training workload over numerous devices. Such capability is highly important in contemporary networks where the massive amount of data produced by connected devices needs to be processed and analyzed quickly and accurately. In addition, FL makes IDS more flexible. With distributed collaborative learning, the IDS continually refreshes its models using data on new threats detected on other devices. That flexibility allows the IDS to better detect and respond to new and emerging threats, including those that may circumvent a traditional rule-based IDS, as well as more advanced ones.

Table 3: Summary of approaches and challenges in intrusion detection using federated learning

.Ref	Objective	Technique	Challenges
[34] ,[33]	Reduction of False Alarms	Semi-Supervised Learning, FL	Model aggregation issues, Data scarcity, Resource limitations, Attack evasion
[35]	DDoS Attack Detection	FL	Complexity of attack patterns, Early-stage FL limitations
[36]	Privacy Protection	FL	Risk of data breaches, Data vulnerability issues
[31]	Network-Based IDS	FL, Semi-Supervised Learning	Network variability, Data heterogeneity
[19]	Real-Time Detection	FL, Incremental Learning	Communication delays, Model synchronization challenges
[12]	Multi-Source Detection	FL, Ensemble Learning	Data inconsistency, Model divergence

1) **FL for Detecting DDoS Attack:** DDoS attacks are an ever-increasing danger to the cybersecurity world. The objective of a DDoS attack is to deplete and take control of the resources of the targeted system by executing a DoS attack through multiple computer systems [37]. Therefore, DDoS attack detection is critical for preserving the Quality of Service (QoS) of the users. Recently, FL has been gaining wider attention from practitioners and researchers regarding DDoS attack detection. Nevertheless, for the application of FL within IDS, development is still at an early stage [35].

2) **Privacy Preserving through FL:** An IDS focuses profoundly on information protection relative to external harm be it confidentiality, integrity, or availability. Compromising user data privacy is a possibility during data collection for an anomaly detection statistical model, and therefore the model's dataset has to be large. Most existing Deep Anomaly Detection (DAD) systems suffer from two major privacy issues: having vast amounts of unprotected data in one place such as a server and sending or retrieving the data through unsafe communication networks [36].

3) **FL-based IDS for Computer Networks:** The different scales of connected devices give rise to various forms of networks such as Satellite Networks, Personal Area Networks (PAN), Local Area Networks (LAN), Metropolitan Area Networks (MAN), and Wide Area Networks (WAN). The effectiveness of these networks is affected by the users' heads, network congestion, distance of nodes, and traffic [20]. An FL framework for IDS must be developed for each case in particular, taking into consideration the data generated, the expected data type, and the intercommunication of clients and devices. These considerations align with the anticipated attack's nature and its potential impact [31].

5. Future developments in intrusion detection with federated learning

The introduction of FL carries new trends and developments in the field of IDS. One of the most important trends is the use of artificial intelligence (AI) and ML components in FL-based intrusion detection systems. Using modern algorithms and models, detection methods and their flexibility within the IDS have immensely improved. There is increasing use of FL in cloud-based IDS.

As more people rely on cloud computing, FL helps IDS take advantage of the computation power available in the cloud making it easier to scale and handle large amounts of network traffic without compromising privacy and security. In addition, the implementation of FL-based IDS is facilitated by the availability of FL frameworks and libraries. These frameworks and packages provide basic instruments and interfaces for components' integration, which simplifies the system's implementation and greatly enhances efficiency.

6. Conclusion

Deep learning (DL) techniques for intrusion detection are generally more resource-intensive than traditional methods, including conventional machine learning (ML) approaches. The challenges posed by implementing resource-hungry DL algorithms as a result of their increased CPU and memory resource requirements are considerable. The ability to enable intelligence on the edge as well as provide data privacy with high agility, low latency, and efficient energy use is what Federated Learning (FL) brings to the table to help solve most challenges. FL has rightfully become a popular solution in many areas of privacy-sensitive computing where FL has many applications and is constantly maturing. Despite that, FL methods suffer from a serious drawback regarding communication load in each training cycle. The intrusion detection data is already difficult to classify and adding data complexity makes it even more challenging. FL is beneficial when dealing with large datasets, but an extremely heterogeneous dataset can lead to poor performance of local and global models, which subsequently leads to an excessive number of false positives.

The use of FL-based IDS can largely change the cybersecurity domain. Long-lasting improvements in privacy-sensitive methods, federated meta-learning algorithms, and communication protocol design enable the construction of resilient and scalable IDS solutions. FL in combination with privacy preservation offers a promising way to ensure the security of the interconnected world.

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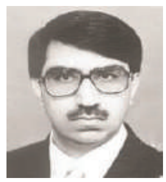

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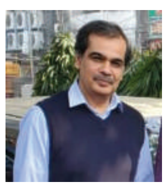

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A black hole is a massive, compact astronomical object so dense that its gravity prevents anything from escaping, even light. Albert Einstein's theory of general relativity predicts that a sufficiently compact mass will form a black hole. The boundary of no escape is called the event horizon. A black hole has a great effect on the fate and circumstances of an object crossing it, but has no locally detectable features according to general relativity. In many ways, a black hole acts like an ideal black body, as it reflects no light. Quantum field theory in curved spacetime predicts that event horizons emit Hawking radiation, with the same spectrum as a black body of a temperature inversely proportional to its mass. This temperature is of the order of billionths of a kelvin for stellar black holes, making it essentially impossible to observe directly.

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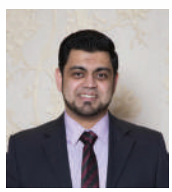

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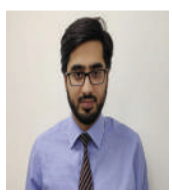

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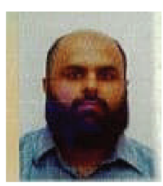

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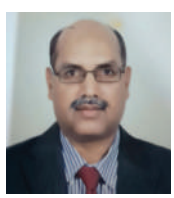

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Who invented electricity?

The discovery of electricity happened over several centuries, going back to Ancient Egypt and the understanding of electric fish, which produced a shocking and numbing effect on skin. Electricity as we know it today wasn't invented, but it was discovered by many scientists and philosophers over the years, including Benjamin Franklin.

Benjamin Franklin was one of the Founding Fathers and spent years researching electricity. In 1752, Franklin conducted his famous kite experiment, where he attached a small metal key to a damp kite string and flew the kit during a storm. As a result, electrical sparks jumped down the kite string.

Other scientists, including Michael Faraday, Alexander Graham Bell, and Nikola Tesla, contributed to the understanding of electricity. Through years of research, electricity evolved into the power source we know today.

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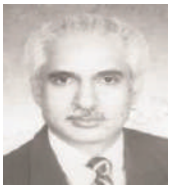

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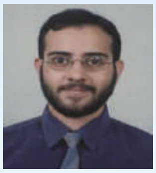

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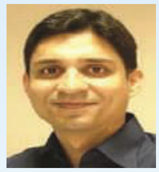

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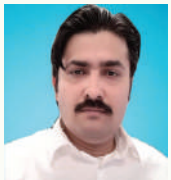

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- Beauty is eternity gazing at itself in a mirror.
- Progress lies not in enhancing what is, but in advancing toward what will be.
- In the sweetness of friendship let there be laughter, and sharing of pleasures. For in the dew of little things the heart finds its morning and is refreshed
- Of all possessions a friend is the most precious
- Trust in dreams, for in them is hidden the gate to eternity.
- If you reveal your secrets to the wind, you should not blame the wind for revealing them to the trees.
- If your heart is a volcano, how shall you expect flowers to bloom?
- Love and doubt have never been on speaking terms.
- Wisdom ceases to be wisdom when it becomes too proud to weep, too grave to laugh, and too selfish to seek other than itself.
- Sadness is but a wall between two gardens.
- Keep me away from the wisdom which does not cry, the philosophy which does not laugh and the greatness which does not bow before children.
- Only when you drink from the river of silence shall you indeed sing. And when you have reached the mountain top, then you shall begin to climb. And when the earth shall claim your limbs, then shall you truly dance.
- The teacher who is indeed wise does not bid you to enter the house of his wisdom but rather leads you to the threshold of your mind.

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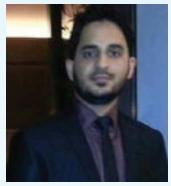

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