

WELFARE OF MASSES

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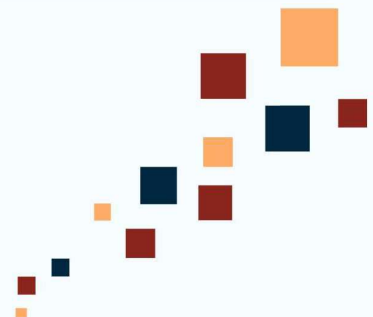
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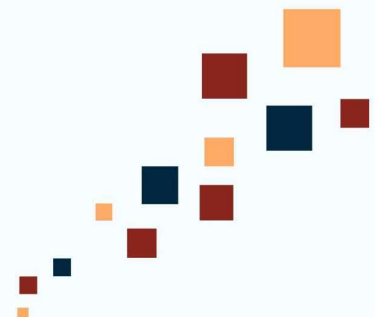
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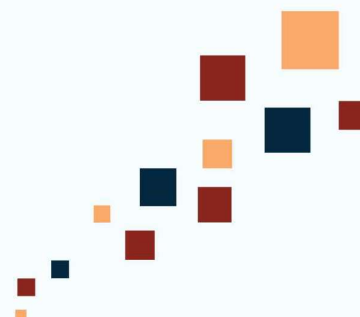
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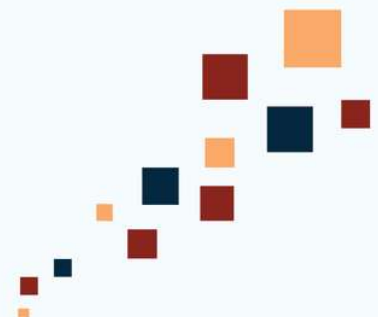
President's Message

The Marathwada Mitra Mandal was established with a deep sense of commitment towards uplifting the underprivileged sections of the Marathwada region. The motto of Welfare of Masses began a modest initiative that has grown into a distinguished educational movement, rooted in the ideals of service, inclusivity, and social responsibility. Over the decades, we have strived to create an environment fostering not just academic excellence but also the holistic development of all our stakeholders.

It gives me immense pride and joy to witness the release of the second edition of our interdisciplinary, peer-reviewed research journal Welfare of Masses. This journal stands as a testimony to our commitment towards promoting research, innovation, and dialogue across diverse fields for the betterment of society. I extend my heartfelt congratulations to the editorial board, contributors, and reviewers who have dedicated their expertise and energy to bring this scholarly endeavour to fruition.

As we move forward, we envision our research journal Welfare of Masses growing into a respected platform that inspires original thought, bridges academic disciplines, and addresses real-world challenges. With the spirit of Jai Jawan, Jai Kisan, Jai Vigyan, Jai Anusandhan, let us continue to unite our efforts for the progress of our nation and the welfare of humanity at large.

Prin B. G. Jadhav
President
Marathwada Mitra Mandal



From Editor's Desk

It is our privilege to present second volume of this journal as a platform for academic excellence & interdisciplinary research. Guided by the vision of “Welfare of the Masses” we strive to promote knowledge that is innovative, inclusive, and socially relevant.

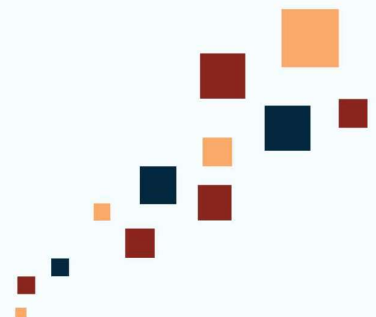
Our focus spans across a broad spectrum of disciplines—including Commerce, Management, Social Sciences, Physical Sciences, Engineering, Humanities & Education.

We firmly believe that real progress emerges when diverse fields of knowledge interact & collaborate, offering fresh perspectives and holistic solutions to complex issues.

By engaging with national & international academic communities, we seek to foster dialogue, exchange of ideas, and meaningful research contributions. We welcome original works that embody integrity, innovation & impact and remain committed to nurturing a research culture that serves society and contributes to global knowledge.

On behalf of the Editorial Board, we extend our sincere gratitude to the authors, reviewers & readers whose support strengthens this platform. We warmly invite scholars & practitioners to join us in this endeavour of knowledge creation & dissemination, with the hope that our collective efforts will inspire meaningful change and academic progress.

Dr. Kishor Nikam
Editor



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A Study Of Workplace Anxiety Amongst Gen Z Employees In The Manufacturing Industry

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ABSTRACT

This paper presents the research about workplace anxiety which is one of the common factors emerging nowadays in organisations between the Gen Z employees. It has become a significant concern, as the professional surroundings create tension, stress, anxiety etc. This study analyzes the major causes, effects, and how they cope up and also the solutions to it.

Secondary data is collected from journals, articles, online sources and also industry reports. Working is a mandatory part of this world; it reveals that work is a major driver of anxiety and fear among young workers. They majorly go through job insecurities, competition, heavy workloads, lofty expectations, no proper management of work-life balance and some of the psychological factors that feed the anxiety and contribute to its growth. Due to which Gen Z struggles mentally, and receives mental isolation and loneliness. According to this analysis, nearly (74%) of Gen Z's contending with anxiety (Deloitte, 2025). There are many key psychological factors that Gen Z goes through which cause them to be distraught. The factor that majorly affects is the dependency on technology, and there is huge progression in living ways, technology influences and causes changes in biological functioning and mental health, due to which hormonal imbalance, brain functioning, response system is disturbed. These forthcoming generations are not weaker but they have become more dependent on technology and digitalisation, changes in lifestyle which makes them face mental challenges. Their resilience and sustaining nature have reduced and caused pressures like FOMO (Fear of missing out), and minimised real-life interactions. This study went under a crisis of anxiety, why they face it.

INTRODUCTION:

Generation Z is a gang of individuals born between 1997 to 2012 (Pew Research Centre, 2023), they are facing the major part of digitalisation and technological changes. Dynamic advancements in every sector have increased the competition.

As this generation plays a vital role in designing the modern workplaces and development. Further with these advantages and strengths, there is a crisis faced by them that is workplace anxiety. Core problem: “Why Gen Z employees are experiencing higher workplace anxiety” This generation is very active and has profound insights regarding the future.

The digitalisation has absorbed their independent working, Real-life interactions, brain functioning and many other factors. This causes emotional well-being to be damaged, and they face (FOMO), pressure from family, anxiety of competition, job insecurity (Latupeirissa & Cistadewi, 2025), lack of skills etc. How individuals develop themselves by preparing them for the future.

is that they need to analyze the identity formation which means oneself development. They need to understand who they are, career identity, values and beliefs, etc. This process for Gen Z employees has become complex due to digitalization and offline working as well. Self-realisation where you access yourself for the development which is essential during late adolescence and early adulthood, they are capable of creating multiple identities but stress out to manage them.

Studying this is essential As Gen Z employees are stepping in the rapidly changing work environment so it is important to analyse their mental and emotional working, challenges they face, to help them transition into professional surroundings. They face a variety of personalities. When they feel lagging between their build up professional personality and expected one this generates internal conflicts, high expectation pressure etc.

The main objectives of this study are:

They need to understand what they can sustain? What can their body go through? They need to understand their potential and work with it. To know why they face anxiety? Why do they stress

out? What type of pressure do they face? What actually companies can do to reduce the stress? To give solutions/ measures to reduce workplace anxiety.

LITERATURE REVIEW:

There have been several studies done to look forward to this problem, and examine the mental health, behavior, psychology of the Gen Z employees.

The study by Nidya Dudija and Muhammad Dzaky Apriliansyah where they have studied the Human Resource management role in development of Gen Z employees, their mental health etc. (Nidya Dudija & Muhammad Dzaky Apriliansyah 2024)

The international journal of Indian psychology: Psychosocial aspects of generation Z: Review the study by Dr Jayesh Ghodke, Akanksha Gupta, Ishita Shah and Yahvi Singh.

The review is about the formation of identity and its complex formation in Generation Z and how a variety of things influence it. They also studied the foundational theories by Erikson and Marcia. The various factors such as sociopolitical changes, digitalisation, lifestyle evolution, exploration of oneself, psychological stress etc. They found causes of social comparison where cyberbullying, social media, makes face the challenges related to mental health and identity establishment. (The international journal of Indian psychology: Psychosocial aspects of generation Z: Review)

Generation Z: A Review and Research Agenda study by Afshan Zoya, Dr. Pradnya V Chitrao, they looked forward to the generation difference between Gen Z and Gen X and Gen Y. Why this generation is more prominent and their work approach is unique. They also spoke about the creative, musical enthusiastic culture amongst Gen Zs. But they also say that without any understanding, studying about this generation the recruiting and retention of these may affect the organization. (Afshan Zoya, Dr. Pradnya V Chitrao)

A Review on “Quiet quitting” is a concept of behavior where employees work without emotional engagement or assurance to the organizations. It

also says that this quitting thing has increased in the Gen Z as they are too much adapted to the digital mesh. (Tia Oktavia, IGAA Noviekayati, Suhadianto, 2025)

These generations face a lot of burden, coercion which imbalances their daily life working due to which they don't take extra tasks, do not get much involved in events of organization or extra work. So, the demands of work and psychological well-being need to be balanced.

For the Data analysis and interpretation, the factual information by Deloitte Global Gen Z and millennial survey 2025 is studied and determined the factors contributing the workplace stress/anxiety (Deloitte, 2025)

McKinsey Health Institute

ESCAP European Society for Child and Adolescent Psychiatry (Mental Health Matters) Generation Z's perspectives on mental health- a study by the McKinsey Health Institute

The McKinsey Health Institute surveyed 6,000 Gen Z respondents across 10 European countries (France, Germany, Italy, the Netherlands, Poland, Spain, Sweden, etc.) to understand their views on mental health.

Survey results were consistent with what respondents in the United States said in January 2022: Gen Z reports poorer mental health when compared with older generations. Specifically, climate change, the war in Ukraine and COVID-19 were noted as contributing to high distress.

Comparing generations, Gen Z has higher levels of mental health problems (reporting "poor" or "very poor" mental health is about 20%)

Results showed that the stigma of mental health issues amongst Gen Z is still high – both in terms of society's perception as well as one's own perception. In fact, Gen Z were more likely to see mental health illnesses as the result of poor upbringing or a character flaw.

In addition, direct health-related support measures play an important role in job choice. On average 67% of Generation Z respondents said that availability of behavioural-health resources was important when selecting their employer. (McKinsey Health Institute, 2022)

WHO World Health Organization Mental Health at Work 2 September 2024

Decent work is good for mental health. Poor working environments- including discrimination and inequality, excessive workloads, low job control and job security- pose a risk to mental health. 15% of working-age adults were estimated to have a mental disorder in 2019.

Risk to mental health at work include: Under-use of skills or being under-skilled for work;

Long, unsociable or inflexible hours;

Unsafe or poor physical working conditions;

Limited support from colleagues or authoritarian supervision; etc. (WHO, 2024)

GALLUP State of the Global Workplace 2026 It reports features annual findings from the world's largest ongoing study of the employee experience. The 2026 edition finds that global employee engagement fell to 20% in 2025, its lowest level since 2020.

Key findings; In 2025, global employee engagement declined for a second year to its lowest level since 2020.

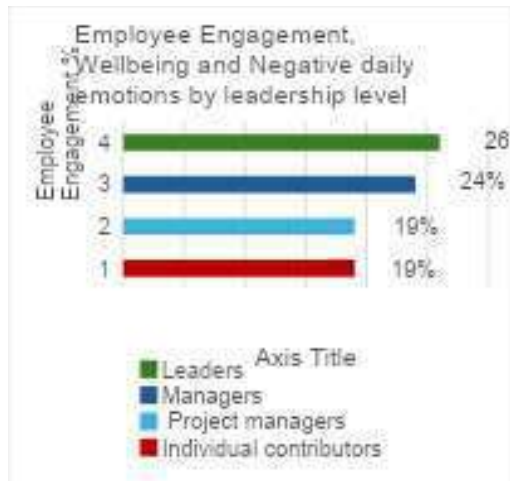
The global employee wellbeing improved for the first time in three years.

Gallup research finds the percentage of employees who report experiencing a lot of stress, anger or sadness the previous day remains above pre-pandemic levels; Daily negative emotions among workers increased worldwide during the pandemic. Also, well-being increases when employees see their work as intrinsically rewarding and good for others.

Leaders have higher life evaluations but worse days than those they lead, according to Gallup data. (GALLUP, 2026)

Workplace mental health challenges continue to grow, with rising stress and anxiety levels reported by U.S. workers. SHRM surveyed more than 1,100 U.S. workers in February 2026, uncovering concerns about burnout and underutilization of mental health benefits. (SHRM, 2026)

PEW It's Time to create Mentally Healthy Workplaces| The Pew Charitable Trusts [pew.org](https://www.pew.org) Trend Article| Dec 8, 2023.



(GALLUP, 2026)

SHRM 2026 Mental Health Snapshot

Here, the report says workplace mental health came into sharper focus during the pandemic and the racial justice reckoning. Their nonprofit organisation conducted a landmark study in 2021 where they surveyed 1,500 U.S adults in full-time jobs, and there was representation across race, gender, levels of seniority, etc. They found that mental health challenges are pervasive among employees. More than 75% of respondents reported at least one symptom of a mental health condition.

One workplace factor negatively affects their mental health. Younger workers in Gen Z and Millennial cohorts were affected more severely. (PEW, 2023)

MONTCLAIR STATE UNIVERSITY, Why Gen Z is More Anxious than Ever? Turning to social chats for answers by DR. YI Luo, Dr. Jin-A Choi, and Dr. Bond Benton

Gen Z includes individuals born between 1917 and 2012, They have grown up with smartphones, the internet, and social media. The major influencing factors were COVID-19 pandemic, Climate change, Social, political and economic instability. Gen Z is highly active and concerned about social and global issues.

They found the primary causes of Anxiety: Social media, Uncertainty about future, Pressure to maintain perfect online image due to which the stress, anxiety increases, feeling of loneliness insecurity is generated.

Its findings on What were the general sentiments and emotions surrounding the topic of anxiety among Gen Z? About 65% of Gen Z posts analyzed showed negative sentiments, while fear was identified as the most common emotion, accounting for 83% of all emotions expressed. Gen Z members openly discussed how anxiety affects many areas of their lives, including finance relationships, social interactions, work, and everyday activities. They also found that anxiety places a significant emotional and psychological burden on Gen Z. (MONTCLAIR STATE UNIVERSITY)

OBJECTIVES OF STUDY:

1. To know the major causes of the anxiety amongst Gen Z's
2. To study to what extent Gen Z can experience anxiety at the workplace.
3. To examine the impact of workplace anxiety.
4. To study the role of organizations in managing workplace anxiety and promoting employee well-being among Generation Z employees
5. To understand the emotional response of Gen Z and their psychological working.

NEED OR RELEVANCE OF THE STUDY:

Work is a crucial part of the organization where no. of employees are working together of different culture, language, psychology, attitude etc. also the digitalization makes the difference. While adjusting with this there is a high increase in the levels of pressure of work while meeting the individual and organizational goals. Gen Z organizations have stepped into the new modern era, with that they have to face multiple challenges and consequences based on their working pattern.

In today's rapidly growing world, evolution and its needs must be analyzed. Gen Z has a vital role in today's digitalization and they are aware about it, But the consequences they face are not always positive. They are facing work load pressure, long working hours, digital fatigue (WHO,2022;

McKinsey Health Institute, 2022) job insecurity, lack of recognition and this affects their mental health.

It is very essential that employees should work with a healthy mindset in the organisation; this impacts their daily productivity. Organizations should be concerned about the Work-life balance of employees and set working hours according to it.

The study is essential to scrutinize the psychological factors that provoke anxiety, pressure. Also, how employees can manage them. The organization should maintain a healthy, positive, motivating environment. Should have various health related sessions and practices in the organization. This Research speaks about some of the most prevalent factors and also looks forward to developing the working and wellness strategies to support a healthy work-life balance.

The study is relevant because:

It analyzed the social, psychological, impact on Gen Z employees that generates workplace anxiety.

Also, underlines the role and impact of excess digitalization and competition.

It also helps the organization to understand the employee and look forward towards his well-being.

Also, how they can maintain the potential employees in their organization and

RESEARCH METHODOLOGY:

The study is in descriptive research form which approaches the understanding of workplace anxiety faced by Gen Z employees. Analyzing the stress, anxiety level among Generation Z employees and searching for the triggering factors.

1. Research Design: This research complies with the descriptive research design, completely concentrating on the Gen Z employee's psychology, behavior, way of handling various problems and stress management and is there any impact on the work they perform.

2. Data Collection:

Primary data: The data is collected from various types of working Gen Z employees in Manufacturing and other companies. Some of them

are interns, Contract employees, Permanent Employees, Apprentice etc.

Sampling Technique: Convenience Sampling

Sample Size: 20 Generation Z employees

Research Instrument: Structured Questionnaire

Manufacturing sector

Secondary Data: This data was collected via various Journals, articles, research papers, industrial data was studied to make this work worthwhile.

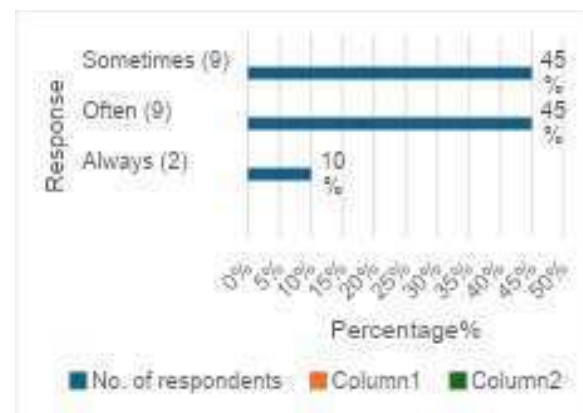
3. Data Analysis tools: The data is analyzed via statistical and graphical methods. To find the percentage of employees facing stress, pressure, and how it affects their productivity and the organization. The major tools used are Microsoft Excel.

4. Limitations: The responses from the Gen Z employees were limited which may not stand for the entire generation Z workforce. Also, there was the constraint of time, and faced geographical limitations.

DATA ANALYSIS AND INTERPRETATION: PRIMARY AND SECONDARY DATA

Primary data

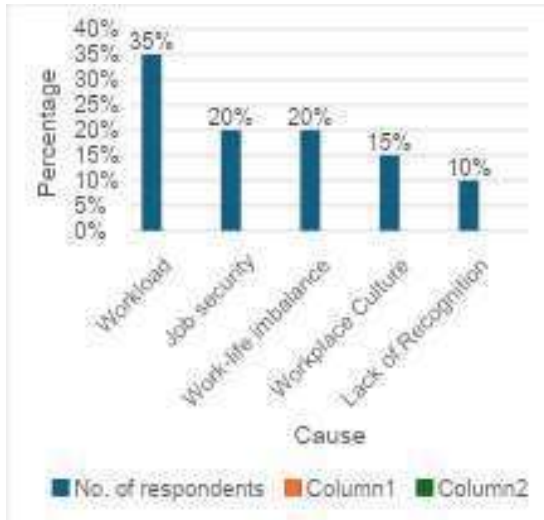
1. Frequency of Workplace Anxiety



The above analysis is made based on the Gen Z respondents where anxiety is a prevalent factor. The majority of respondents (90%) reported experiencing workplace anxiety “Sometimes” or “Often”, and the remaining 10% reported anxiety is experienced always. This presents that the stress,

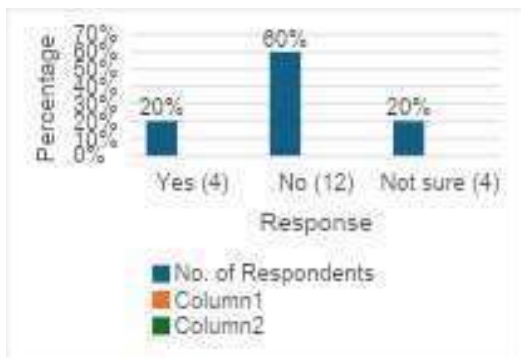
anxiety are highly concerning factors among the Gen Z employees and may affect their productivity, development, and well-being.

2. Major causes of Workplace Anxiety



This data analysis revealed that Workload, Job insecurity, Work-life Imbalance, Workplace Culture etc. these are the substantial factors causing anxiety, stress among the employees. Workload and job security are the high contributing factors for causing anxiety which is accounting for 35% and 20% of responses. Work-Life imbalance came up as the second essential factor, which accounted for 20% of the responses. Other causes accounted for 10% to 15% of response. Where organizations should focus on workload management, job security, and employee work-life balance to reduce employee anxiety, stress levels.

3. Organizational Support for Mental Health

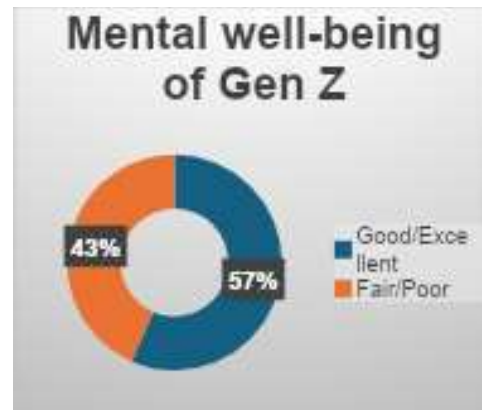


The analysis shows that a major response (60%) is that organizations do not provide the necessary support for employee's mental well-being. Only

20% of employees received the expected support and the remaining were not sure. This analysis culminates the need for organizations to strengthen their mental health policies.

Secondary Data

1. Mental well-being of Gen Z Employees.



(Deloitte Global Gen Z & Millennial survey, 2025)

In the above given graph, the mental well-being of Gen Z employees is determined in two different types in percentage, where the good /excellent is 57% and Fair/poor are 43% These employees actually face the stress, anxiety which affects their mental health (well-being). It says that the no. of stressed ones should be reduced and well-being must be enhanced and looked for.

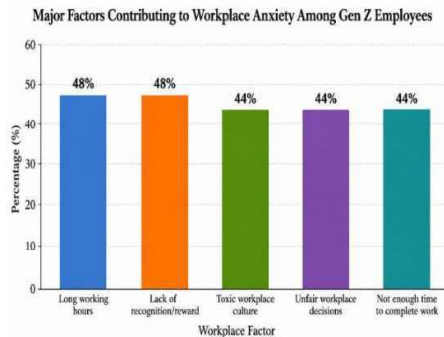
2. How many Gen Z employees feel stressed or anxious regularly?



The above graph mentions the significant percentage of Gen Z employees that face stress anxiety frequently; it says that mental health, mental well-being has become a vital concern

among the upcoming young employees. But the majorly standing out are (60%) employees who do not experience the stress daily.

3. Which are the major factors that cause stress?



(Compiled by the Researcher)

The bar graph given above presents the prevalent factors such as (Long working hours, lack of recognition/rewards, toxic workplace culture etc.) that affects the Gen Z employees in a negative way and creates the edge of pressure amongst them. The toxic workplace culture, unfair workplace decisions and not having enough time to complete work causes pressure on 44% of respondents. Overall, the data underlines the unhealthy work culture, organizational pressure.

RESULT/FINDINGS:

The analysis of respondents stated various triggering factors like (Workload, Job insecurity, Work-Life Imbalance, Workplace Culture, Internet, Media etc.) for causing stress, anxiety. Half of the respondents expressed dissatisfaction with the work-life balance provided by organizations. With this all of the respondents agreed that organizations should look forward and prioritize employee mental health to reduce workplace anxiety.

One of the highly affecting factors is the long working hours that causes about 48% of respondents to face stress. Excess digitalization, also causes the stress and pressure psychologically on employees as it affects physical and mental state both.

Lack of Recognition sometimes, because it is important to make employees feel their hard work is worth it and when it lacks it generates dissatisfaction and only pressure of work increases.

About 48% of employees reported about it (Cite Deloitte, 2025)

Pressure of time, unfair workplace decisions, no proper work-life balance due to which employees are exhausted mentally and this affects their day to day life. Overall organizational workload, working hours, family pressure, management of expenses, these are the prevalent factors that produce pressure, anxiety and affect work efficiency. Sometimes the Gen Z employees keep on working emotionally and get depressed.

According, MONTCLAIR STATE UNIVERSITY, Gen Z have grown up with smartphones, the internet, and social media, and as they are connected socially and are affected by social, economical issues. They get the feeling of loneliness, insecurity, pressure of creating a perfect online image etc.

Workplace anxiety is a negative factor that affects the employee's productivity, job satisfaction, also the mental health and positive emotional permanence.

SUGGESTION/RECOMMENDATION

1. Should arrange the wellness programs in the organization.
2. Reduce unnecessary extra hours working.
3. No excessive digital dependency
4. Should look forward for a healthy work-like balance
5. Time to time recognition for the work and also the various creative programs for skill enhancement.

CONCLUSION

The analysis states that the workplace anxiety is a serious concern that is negative and damages psychologically and emotionally. Also, it is potent due to high digitalization, long working hours, job insecurity, FOMO (SSRN eLibrary), responsibilities, managing expenses, toxic work culture. There should be strategic work management, smart working and proper work-life balance by organization for employees. This enhances productivity which leads to organizational growth.

Good mental health keeps employees happy, satisfied and enthusiastic. Due to the excess adaptability, the digital dependency has increased due to which they may experience the psychological pressure caused by change in career expectations, digital exposure, media, job insecurity etc. They are not able to sustain heavy working and this affects their psychology (hormonal disruption, weak mental ability and laziness) but with that Gen Zs are prominent and highly active and must track their daily work progress. (Deloitte, 2025; McKinsey Health Institute, 2022; WHO, 2022).

They are creative and contribute a lot to today's upgrades and development. This is a positive point for organizations and beneficial with time as civilization is increasing rapidly, modernization, and they are tech-enabling. By undertaking all of these pros and cons organizations should look towards this issue in a strategic and effective way.

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These references give the Authentic and actual information and research that supports the observations, findings, presented in this research paper.



Constitutional Regulation of the Right to Protest in India: Framing Guidelines for Democratic Governance in the Post-2025 Era

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ABSTRACT

The right to protest is protected as an integral part of democratic participation in India in the constitution under the provisions about freedom of speech, assembly and association (Article 19). Protests since 2025 have shifted in nature to be more digital, decentralized, occupy public space for longer and more polarized. These events have intensified the conflict between individual rights and the need for public safety, economic security and social harmony in the Constitution in recent years. This has created inconsistent responses by the authorities and legal uncertainty about the protests since there is no clear national framework for responding to protests. This article examines the right to protest from a constitutional and doctrinal perspective, examines some of the key court decisions, and illustrates how contemporary protest movements are creating new issues. The paper proposes a rights-based approach to structuring national protest rules based upon the theory of proportionality and comparative regulatory approaches. The paper maintains that it is necessary to have constitutional balance and strengthen the process of good governance, which involves protecting and controlling democratic dissent in an evolving socio-political environment.

INTRODUCTION:

The power of protest constitutes one of the most potent ways in which citizens exercise themselves politically, and it is an inherent part of constitutionalism in contemporary democracy. It is

through social unrest, legal reforms, and political shifts that social dissatisfaction in India throughout its history has led to action. Protest, therefore, was a mechanism employed by citizens to express their

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displeasure, ask questions about any biased policies and call upon their leaders to be answerable for the same. Therefore, when one protests, it is not merely a political act, but rather it is the assertion of one's power to do so under the Constitution.

The structure and character of protest movements in India, have changed drastically in the last several years, especially after the year 2025. In contrast, agitations are more widely spread than they used to be, and technologically mobilized, and now facilitated by social media networks, which were not so prominent in previous years when the agitations were coordinated by distinct organizations or leaders. Such protests have often taken the form of symbolic protests involving the closing of roads, occupations of buildings, vandalism and destruction of properties. While such protests reflect a higher degree of involvement by citizens in their government, they have resulted in several negative consequences such as the disruption of transport, financial losses and even issues of law and order.

Given recent trends in protest, one of the perennial issues of the constitution is now more pressing: protecting individual rights and preventing social disruption, crime, and tranquillity. The freedom of speech and expression, freedom of assembly peacefully, and freedom of association rights are enshrined under article 19 of the Indian Constitution. But what one must realize is that these freedoms are not absolute in nature and can be restricted for certain reasons. There are no clear laws that regulate protests and these have been managed through legal legislation, emergency powers and executive decrees of government from the colonial era.

As a result of the inconsistencies and often arbitrary responses in different places, legal uncertainty and allegations of rights abuses have followed. Since the lack of a unified national framework, there are no constitutional principles for authorities and citizens to operate in. Court rulings are still very reactive and case-specific, rather than systematic, despite judicial efforts to fill this gap. Given the above, it is the paper's contention that a rights-based regulation of protests is absolutely essential in India, which is aimed at preserving public order and the continuance of

governance without infringing on democratic freedoms. The system could also incorporate judicial review and develop on the principle of proportionality to strike a constitutional balance between the protection of democratic dissent and its abuse.

1. RESEARCH PROBLEM

Even though freedom to protest has been enshrined in Article 19 of the Indian Constitution, India does not have a well-developed set of laws relating to public protests. Several judicial decisions have thrown light on how the issue needs to be handled, but the lack of uniformity and clarity in such interpretations has resulted in an ambiguous situation regarding the balancing act between constitutional rights and public order. The new form of digital protests, which have become common since 2025, has only highlighted the inadequacy of the existing law.

2. LITERATURE REVIEW

Bhattacharya et al (2022), had explored the possibility of how India's constitution successfully held the country together despite the multiplicity of political expressions. They had found that citizens could participate in India's democracy in a number of different ways, one of which was through public demonstrations. These, however, it was remarked by the authors, were not uniform responses from the authorities, particularly at large-scale agitations, as there was no single regulatory framework for civic activity. Their aim was to argue that resilience of a democracy was not found in the suppression of dissent, but in the creation of institutional mechanisms to address social conflict without undermining the constitutional rights or liberties. Their research did much to deepen our understanding of the reasons why the Indian government has often resorted to emergency powers and prohibitors orders when there were no known precedents for the way to manage protest.

Earlier Aboh (2024) had presented a discourse-based perspective through social media posts of narratives from the #EndSARS protests in Nigeria. His studies had revealed that individuals could circumvent the traditional political channels using digital platforms, and that these platforms

were transforming the nature of protest into a global phenomenon. The findings revealed how online speech contributed to the increase of emotional expression, the activation of collective identities and more, affecting popular opinion on the state. The line between nonviolent protest and violent political opposition becomes more blurred in online protest venues, according to Aboh, who also found that this makes government regulation more difficult. His work is particularly important for post-2025 protest movements increasingly dependent on social media for co-ordinating, exposing and establishing credibility. The study's results highlight the relevance of digital speech in modern protest governance as a part of constitutional expression.

Novitz (2019) previously examined free association as a theory of the collective activity. She had tracked the development of association rights through history and highlighted their key function in maintaining democratic participation. In her previous research, she had claimed that constitutional systems' participatory cores were threatened by the erosion of communal freedoms. Novitz sees a worldwide movement towards securitization, which increasingly seeks to name dissent as a threat rather than a democratic right, in the growing regulation of assemblies and associations by the state. This theoretical framework had offered some justification for the notion that constitutional societies ought to be careful in their policing of protests for fear of eroding their democratic institutions.

Schupmann (2024) had already explored the apparent paradox of liberal constitutional systems that promise to protect democratic freedoms, but also limit them to protect these freedoms. His notion of 'militant democracy' justified the restriction of individual freedoms in constitutional states, in order to maintain the democratic system. The limits, according to Schupmann, tend to normalize emergency powers and surveillance techniques over time, even though that wasn't their initial intention. His work had established that, without robust judicial oversight and protection against proportionality, a democracy has the danger of becoming a permanent tool of government. Theoretically, it had played an important role in understanding the conflict

between individual freedom and governmental regulation in protest governance.

Kryder et al. (2023) have introduced a practical educational element by studying staged police and protester confrontations in a polarizing election. Their results provide insight into the complex network of legal and political restrictions on the interaction among protesters, the public, and institutional actors. The research shows that often the escalation of the confrontations is due to the absence of clear regulatory norms, harsh enforcement practices and misunderstandings between parties. The writers had come to the conclusion that in order to keep democracies from collapsing during large-scale protests, there needed to be clear legislative guidelines and procedures for structured debate.

3. RESEARCH METHODOLOGY

For the purpose of examining the constitutional framework of protest in India, this study uses the qualitative doctrinal legal research approach. The data for the analysis of the problem will consist of constitutional provisions, decisions of the Supreme Court, statutory enactments, Law Commission Reports, and peer-reviewed academic journal articles. Comparative constitutional law will also be used in order to analyze the laws relating to the regulation of protests in some selected democratic countries. The sources of information to be used in this research study will be purely secondary, with emphasis on the constitutional interpretation and principles of law.

4. CONSTITUTIONAL BASIS OF THE RIGHT TO PROTEST

Protest in India is protected in the constitutional framework enshrined under Article 19 of the Constitution, even though it is not specifically mentioned as a fundamental right. It is a result of an amalgamation of several other constitutional liberties such as the right to peacefully assemble, right to association, and right to freedom of speech and expression. These combined together provide the constitutional framework through which one can express oneself, assemble in groups, and participate in political discourse. Hence, protesting in India is not a

prohibited activity but rather one of constitutional permission in a perfect democratic spirit.

Whereas on one hand there are these liberties guaranteed under the constitution, on the other hand, these liberties come with a caveat and the state in the interest of public order, national integrity, security of the State, morality, decency, and sovereignty has powers under Articles 19(2), 19(3) & 19(4) to impose restrictions. The objective of the framers in granting these freedoms and limitations was to create a balance between the two extremes. Right to protest is thus a case in point where the idea of conditional freedom takes precedence.

Table 1 presents the constitutional framework that guarantees the right to protest and the laws permitting it under certain conditions.

Table 1. Constitutional provisions supporting the right to protest

Constitutional Article	Nature of Right	Grounds for Restriction
Article 19(1)(a)	Freedom of speech and expression	Article 19(2) – Public order, sovereignty, integrity of India
Article 19(1)(b)	Right to assemble peacefully	Article 19(3) – Security of the State, public order
Article 19(1)(c)	Right to form associations	Article 19(4) – Morality, integrity, public order

Rather than being acknowledged by a single explicit rule, the right to protest is acknowledged by a web of interconnected freedoms, as seen in Table 1. There is a clause that allows the state to put reasonable constraints on each freedom, though. Dissent is protected, but only under certain

The government must not impose a ban on protesting in such a manner that it curtails citizens' rights. However, the government reserves the right to impose a ban on protest if it feels that national interests require it. The point here, then, is that the table brings to light the need for a good regulatory

system that allows the exercise of democratic freedoms without letting things go haywire under the pretext of freedom allowed by the Constitution.

The right to protest is founded on the constitutional basis of liberty and governance. According to the Constitution, the right to voice one's discontentment is a key element of democracy. In addition, as far as dissent is concerned, it is said to be "lawful and in the public interest." It is the basis of formulating further policies that would strike a balance between personal liberties and constitutional duties of ensuring social order and lawfulness.

5. JURISPRUDENTIAL EVOLUTION OF PROTEST RIGHTS

The right to protest in India has been defined in large part by the decisions of Indian courts. Without a clear statute regulating public protests, precedent from the courts has shown how to strike a balance between the right to free speech and the needs of the public. While the judiciary has upheld the right to protest as a fundamental democratic principle, it has also made it plain that protests cannot infringe upon the rights of others or cause disruptions to public life.

In a number of seminal decisions, the courts have struck a middle ground between complete freedom and complete restriction, opting instead for reasonable restraint. In this way, we can see the constitutional principle at work, which states that individual liberties and the common good must coexist. Tabulated in Table 2 are the primary legal concepts that have contributed to this comprehension.

Table 2. Judicial pronouncements on the right to protest

Case	Year	Judicial Principle
<i>Himat Lal Shah v. Commissioner of Police</i>	1973	State may regulate but not arbitrarily prohibit protests
<i>Mazdoor Kisan Shakti Sangathan v. Union of India</i>	2018	Blanket bans on peaceful protests are unconstitutional

<i>Amit Sahni v. Commissioner of Police</i>	2020	Public roads cannot be occupied indefinitely
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Judgment has always attempted to balance individual freedoms against collective considerations, as demonstrated by the examples provided in Table 2 above. It is evident from the judgments that constitutional provisions allow for appropriate restrictions on demonstrations for the purpose of maintaining order and not silencing dissent.

6. CHANGING NATURE OF PROTESTS IN THE POST-2025 ERA

Public demonstrations in India after 2025 became a whole lot different. Today, the process of mobilization tends to be quite decentralized, and people organize through online platforms rather than having clear leaders. Social networks, instant messaging, and other kinds of web resources become crucial components in terms of recruiting supporters, spreading information, and forming opinions. While that has made the citizens more involved politically, the traditional way of controlling public unrest via administrative and legal measures seems to be less efficient nowadays.

The occupations of public thoroughfares, government property, and transportation infrastructure were yet another type of protests we witnessed in recent years. The results of such actions include inconveniences to the population, disruption of the economy, and disruption of important processes. These types of protests only increase the existing political strife and add even more pressure on governmental bodies and law enforcers.

6.1. Major Post-2025 Protest Movements

The nature of protests in India has changed significantly in the post-2025 era. Digital platforms, decentralized organization, and rapid public mobilization have transformed traditional forms of protest. These developments have created new constitutional challenges in balancing the fundamental right to protest with the need to maintain public order, public safety, and effective governance.

Table 3. Major Post-2025 Protest Movements in India

Protest Movement	Year	Constitutional Issue
Bharat Bandh (Trade Unions and Farmers)	2025	Balance between the right to protest and maintenance of public order and essential services
SSC Aspirants' Protest, New Delhi	2025	Freedom of peaceful assembly and expression concerning public recruitment grievances
Gurjar Reservation Protest, Rajasthan	2025	Right to protest versus disruption of railway services and public infrastructure
Digital and Social Media-Coordinated Protests	2025–2026	Regulation of online mobilization, freedom of speech, and constitutional accountability

Table 3 illustrates that protest movements after 2025 have become increasingly decentralized, technology-driven, and digitally coordinated. Unlike conventional demonstrations, these movements rely heavily on social media platforms, creating new constitutional challenges relating to freedom of expression, public order, digital governance, and administrative accountability. These developments reinforce the need for a coherent constitutional framework capable of

balancing democratic dissent with effective governance.

Tabulated in Table 4 are the salient characteristics and constitutional implications of protest movements that will occur after the year 2025.

Table 4. Characteristics of post-2025 protest movements

Feature	Constitutional Concern
Digital mobilization	Difficulty in regulation
Leaderless movements	Lack of accountability
Road and rail blockades	Economic disruption
Political polarization	Law and order challenges

Contemporary protests bring new obstacles for constitutional governance, as shown in Table 3. Both leaderless protests and the usage of digital media make regulatory supervision more complicated and accountability more challenging. Political division and blockages to critical infrastructure compound existing worries about maintaining law and order. All of these shifts highlight the need for new laws that protect basic liberties while also addressing new kinds of protest.

7. BALANCING LIBERTY AND PUBLIC ORDER

The principle that forms part of the Indian constitution is the fact that there must be no conflict between the personal freedom of individuals and the general welfare. It is not the prerogative of anyone to gather together and express their views in any manner which would place the security of other members of the community in jeopardy or trample on the rights of others; however, this is something that should be done within a democratic state. Consequently, through the use of the concepts of proportionality and reasonableness within the constitution, the powers of both the government and individual freedom can be restrained.

This balance is crucial during times of protests. The disruption of essential services, loss in economy, and dangers to people's security can arise from uncontrolled protests, whereas the democratic rights can be restricted by stringent policies. It is a difficult task to formulate a set of laws that would support lawful protests.

7.1. Theoretical Foundations

There are a number of political and constitutional views that argue for a middle ground between individual freedom and public safety. Each of these models presented the argument for the need of particular legal protections and guidelines for protester.

- **Natural Rights Theory** Under the Natural Rights Theory, protest is seen as a natural aspect of human freedom. It believes that people have a moral right to speak out against injustice, and to oppose it, even in the absence of legal systems. In this sense, the State does not give you the right to protest, it gives you the right to protest, as it's a basic human right.
- **Liberal Constitutionalism** Liberal Constitutionalism is based on the recognition of the importance of individual rights in democratic government, while simultaneously rejecting unlimited rights. Under this theory, restrictions can only be justified when the exercise of a right harms another person or poses a threat to public welfare. In protest situations, this principle applies to the extent that it is only allowed if it is necessary to avoid violence, disorder or serious disruption.
- **Democratic Participation Theory** Views protest as an alternative to formal political processes. Protests are another way of participating when institutional avenues are ineffective in resolving public grievances. Yet dissent has to be within the constitutional boundaries that guarantee democratic participation, while, at the same time, maintaining social stability.

These theories offer justifiable support for a balance – that is, respecting the right to protest and ensuring public order and constitutional harmony with reasonable regulation..

8. PROPORTIONALITY AS A CONSTITUTIONAL TOOL

The idea of proportionality is one of the most important constitutional concepts to strike a balance between basic rights and the goals of the state. In cases of protests, the principle of proportionality is used as a safeguard against the imposition of disproportionate or unreasonable restrictions by the State. The doctrine is that any limitation on the freedom to protest should be constitutionally acceptable, well justified, and narrowly drawn — it does not give broad administrative authority or blanket bans.

A demand for proportionality ensures that any limit placed on this kind of freedom is proportionate to the public interest served, for instance, on the grounds of safety, order and stability, rather than simply for the sake of administration. The government also must demonstrate that the government could not achieve the same without imposing the same requirements. Proportionality turns constitutional rights into reality by transforming them into norms of government.

Table 5. Proportionality test in protest regulation

Stage	Constitutional Objective
Legitimate aim	Protect public order and security
Rational connection	The restriction must relate directly to the stated purpose
Necessity	The least restrictive measure must be chosen
Balancing	The harm caused by the restriction must not outweigh the benefit

Judgmental review is and applies to a four-stage proportionality test, which is detailed in Table 4. Proportionality is a "filter" of the Constitution, as demonstrated in Table 4, which is also an "aggregate". For each level we verify that

the restrictions on demonstrations are reasonable and not unreasonable. In order to meet the test, the State gives its reasons for the restriction, its scope and consequences on basic rights. This theory can be used by courts to restrict the exercise of presidential power while at the same time preserving the power to regulate as necessary to preserve public order.

9. COMPARATIVE REGULATORY APPROACHES

Different democratic countries regulate the right to protest through constitutional and statutory frameworks that seek to balance individual freedoms with public order. While the legal approaches vary, most jurisdictions recognize peaceful protest as a fundamental democratic right subject to reasonable restrictions. Examining these regulatory models provides useful guidance for developing a balanced and rights-based framework for India.

Table 6. Comparative regulatory approaches to the right to protest

Country	Legal Framework	Key Regulatory Feature
India	Article 19 of the Constitution	Peaceful protest permitted subject to reasonable restrictions for public order and security.
United States	First Amendment to the U.S. Constitution	Strong constitutional protection of freedom of speech and

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		peaceful assembly.
United Kingdom	Public Order Act	Advance notification and police powers to regulate public assemblies.
Germany	Basic Law (Article 8)	Guarantees peaceful assembly while permitting proportionate restrictions.
Canada	Canadian Charter of Rights and Freedoms	Protects peaceful assembly subject to reasonable limits prescribed by law.

The comparative approaches presented in Table 6 demonstrate that democratic nations protect the right to peaceful protest while permitting proportionate legal restrictions to maintain public order. These international practices support the need for a clear and balanced constitutional framework for regulating protests in India.

10. PROPOSED CONSTITUTIONAL FRAMEWORK FOR INDIA

There is a need for India to have a unified and right-based regulation to strike a balance between public order and violence, on the one hand, and the right of peaceful assembly, on the other. This will ensure that protests continue legally but without disrupting anything to the extent that they can be classified as a form of free speech.

Table 7 summarizes the key principles and measures of the proposed framework

Table 7. Suggested national protest guidelines

Principle	Practical Measure
Recognition of rights	Legal acknowledgment of peaceful protest as a democratic right
Prior notice	Transparent and time-bound permission process

Designated zones	Allocation of safe public spaces for assembly
Digital accountability	Regulation to prevent online incitement and misinformation
Judicial oversight	Fast and independent review of restrictions

The actions listed in Table 6 aim to maintain order and protect the free expression of democratic ideas. This paradigm promotes a balanced approach towards achieving a free and governed society through recognition of rights and acceptable legislation and judicial powers.

11. FINDINGS

The study identifies the following findings:

1. India lacks a consolidated legal regime regarding the right to protest.
2. Judicial decisions are largely based on the doctrine of proportionality in rights versus order.
3. The post-2025 protests in cyberspace and the decentralized nature of such protests pose new constitutional problems.
4. The administration's responses to protests are not consistent in different states.
5. Constitutional practices from other nations require clear regulation of protest rights.

12. POLICY RECOMMENDATIONS

Based on the findings, the study recommends:

1. Enactment of a National Protest Regulation Act based on constitutional principles.
2. Development of Standard Operating Procedures (SOPs) for protest management.
3. Establishment of legal guidelines for digital and social media-based protests.
4. Strengthening of judicial oversight and police accountability in regulating demonstrations.

5. Identification of designated protest zones while ensuring protection of fundamental rights.

13. LIMITATIONS AND CRITICAL EVALUATION

This study is confined only to doctrinal legal research on the basis of constitutional provisions, judicial precedents, legislative enactments, and secondary sources of law. Empirical data is not taken into consideration in this research. Furthermore, the disparities in the legal system can hamper the application of comparative practices in India.

The current legal regime regulating the conduct of protests is patchy and mainly relies on judicial construction of laws instead of an elaborate law. There is also no proper guidance available in the present legal regime about the regulation of digitally organized protests.

14. CONCLUSION

The right to protest is one of the many democratic rights that are enshrined in the Indian Constitution. It is important to understand that because of the absence of any legal framework for regulating protests and the dynamic changes that the protest movements witnessed after 2025, there have been problems in reconciling constitutional rights and public order. It can be seen from the above findings that there is a possibility of regulating protests according to the principles of rights, proportionality, judicial review, and administrative accountability. This will help bring about consistency in the constitution and protect democracy.

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Impact of Fintech on financial innovation in India

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ABSTRACT

Financial innovations in India have completely transformed the way in which finances are handled by millions of people in the country. At the centre of all the financial innovations in the country is the development of the fintech industry over the years. The country has witnessed a significant rise in the number of fintech start-ups that has fuelled financial innovations at all levels. The aim of this particular article is to explore the overall impact that fintech has had on financial innovation in the country. It can be said that the development of the fintech industry has led to innovative solutions that have made things easy for the entire population. Lending and transferring money is just a click away while wealth management can easily be done with the help of numerous digital apps. People have become more aware of their financial decisions and have the necessary resources to invest their money in the right places due to the financial solutions provided by fintech. The article has found that fintech has had a significant positive impact on financial innovations across all levels in the country. It has further been established in the study that the future of financial innovations is quite bright in a country with progressive economic growth.

1. INTRODUCTION:

Fintech is a term that is used to describe the integration of technology that is aimed at improving and automating the use and delivery of financial services in a nation (Goldstein, Jiang & Karolyi, 2019). The development of the fintech

industry is always complimented by financial innovations taking place in a particular region. The fintech industry of India is something that has transformed the way in which people manage and access their finances. The industry has

witnessed rapid growth and is forecasted to proliferate in the coming years. The fintech industry is currently valued at \$584 billion and is expected to rise to \$2.1 trillion by 2030 (Rathore, 2023). The rapid growth and adoption of fintech in the Indian market have been driven by a number of factors like a large and growing population, development of digital infrastructure, thriving ecosystem and efficient government intervention. The rapid growth and development of the fintech industry have helped India emerge as a market leader or global hub for financial innovation. There have been financial solutions that have changed the way in which financial transactions and decisions are made in the country.

India is a country with a huge population of 1.4 billion and this is something that provides significant scope for financial innovation. There has also been a rapid penetration of the internet and the adoption of smartphones in the country which have made it easy to access digital platforms and financial services (Gupta & Agrawal, 2021). Paytm, Phonepe and Google Pay are some of the prominent examples of financial innovations that have revolutionised the way in which the country handles its finances. Another financial innovation that has been supported by fintech in the country is the lending ecosystem of the country. It can be easily established that there is a wide range of financial innovations that have been supported by the development of fintech in the country. From mobile payment solutions to digital lending platforms and insurance technology to wealth management, financial innovation is visible at every stage of financial doings due to the development of fintech (Statista, 2023). The impact of fintech on financial innovation in the country has further had a profound impact on the millions of people in the country. The financial sector has entirely been transformed along with the experience of the people in the country. India is being hailed at the global level for the financial innovations that have transformed the way of making payments and a major role played in it is the development of fintech over the years. The government of India has developed numerous policies and regulatory frameworks that have guided the development of the digital infrastructure in the country and supported financial innovations.

Considering all of these aspects, the purpose of this article is to explore the impact that fintech has had on financial innovation in the country. The relationship between fintech and financial innovation will be investigated in the paper with the help of proper evidence and analysis to provide a more comprehensive account of the subject. The future of financial innovation in the country in light of further development of the fintech industry will also be explored in the research.

2. Literature review

2.1 Review of literature

As per Takeda & Ito (2021), Fintech or financial technology are those innovations that are used exclusively in the financial sectors for providing financial services. In 2008, when the world witnessed the financial crisis, the call for financial innovation started in the world. The term Fintech however is old as it was first coined in the year 1990s and the term was used to provide technological assistance to the backend consumers and the trade financial institutions. The term became popular after the 2008 financial crisis when the world was witnessing the importance and researchers started exploring the Fintech through studying the published journals and later on sharing their experiences through journals. After the year 2016 the research and innovation towards the Fintech started growing as large number of researcher getting interested in Fintech and Financial Innovations.

As mentioned by Suryono *et al.* (2020), digital transformation around the world had created several challenges and opportunities for the businesses and industries around the world. The digital transformation has triggered the emergence to use the technological innovation that is Fintech. Fintech is a technological solution for the financial dealers and customer where it provides a wide range of services. The services which are offered by Fintech are funding, payment, E-wallets facilities, and e-trading options. In the recent year the Fintech trends has risen and it had covered a largest segment of market around the world. Instead of this it has been facing some issues which includes issues in its search process, issues in the implementation of this technology.

As cited by Mention (2019), Fintech over the years is becoming a global phenomenon as more and more countries around the world are using the Fintech. The boost in the Fintech industry has been gained through the participation of India and China in this Fintech trends. The investment in the research and development of Fintech industry is growing day by day as in the year 2018 it had attracted around 12 billion USD investment from around the world. In the year 2018 the top Fintech firms from around the world had raised more than 31.85 billion USD and in future the figures can high as well. Today the Fintech is limited to exploring opportunities in digital payment and the technologies like AI and machine learning hasn't been explored yet. Hence, in future if the technological tools like Blockchain, IoT, AI and Machine Learning will be combined with the usage of Fintech it can revolutionized the future of the financial sector.

As per Chishti & Sinha (2022), financial innovation in India is progress day by day with the successful implementation of UPI system in Indian market. The carbon emission around the world has been increasing around the world and it had completely disrupted the financial section technological and financial innovation. India is the member of BRICS grouping which the group of world top emerging economies in which India, China, Russia, Brazil and South Africa are active members. In the BRICS meeting of the year 2021, the main focus of all the nations was to active sustainability and reduces the carbon emission from the financial process. For achieving this Fintech innovation will be the only option which was proposed and heavily discussed during that meet. According to Rastogi *et al.* (2021), the development and innovation of India's financial sector can be accessed after the launch of UPI whose abbreviation is Unified Payment Interface. This has attracted the world towards its as after the launch in the year 2016 it has become the main source of digital in India. UPI technical has helped to provide the digital payment services options for the poor and lower middle class citizens of India. The advantages of using UPI in India is that it is run and managed by the Government of India and Government doesn't seen any fees for carrying out any transactions through UPI. Hence, introduction of UPI in the Indian market can be seen as the revolutionary step.

As per Khokhar (2021), financial inclusion for all the citizens of the country is the aim decided by the Sustainable development goals in the year 2015. India in the last decade has taken aggressive steps towards the research and innovation of technological sector and the introduction aggressive policies. The government of India in the past few years has launched several schemes to create financial opportunities in India which includes the Start-up India Seed fund scheme, Start-up India investor connect and others. As mentioned by Goswami *et al.* (2022), India is among those countries which are rich in mineral resources, marbles and tourism. The income of the people of India is quite uneven and this unevenness is even more in the rural parts of India. Financial equality and financial inclusion in country like India is quite tricky task to execute. The researcher in this article had tried to highlight this with the help of carrying out systematic literature analysis. In this research there are certain variables that had been found and each of these variables had played a very important role in influencing the rural economy of India. Some of those variables includes social influence on the people, behavioural intentions of the India crowd, trust on the technology and usability.

According to Baporikar (2021), India is a dynamic economy whose number of unicorns are increasing on yearly basis and it is expected to increase further in future as well. The Fintech market of India is expected to reach the level of 2.4 billion USD as of the year by the end of 2020. The market of India has always been cash driven market were people are more depended on the cash for carrying out transactions. The transaction value through the Fintech sector in India was 33 billion USD in the year 2016 and it was expected to reach the market of 73 billion USD as of the year 2020. The growth story of India's Fintech is great but for competitor with the global counterpart it had to create strong pipeline of tech talents in the country and promote the start-up ecosystem in Fintech sector of India.

As mentioned by Painoli *et al.* (2021), Fintech in any part of the world provides alternative solutions for banking services. India is the country where most of the economic policies are made as per the consideration of the poor and farmers section of the society. This is the reason

why most of the banking institutions in India are either government owned or are government undertaking. The financial revolution in the banking sector has been boosted up by the inclusion of Fintech solutions. The market size of India is great hence the success ratio for getting the advances of those Fintech solutions is great. As per Rauniyar *et al.* (2021), financial innovation is one of biggest innovation of 21st century and this has helped many countries to improve their payment options and improve their payment procedure without any interference of cyber-attacks. These days due to technological innovation in the Fintech industries the Fintech solutions which have been invented yet includes artificial intelligence, block chain technology, IoT and the machine learning. The financial turmoil of the year 2008 has created much of devastation around the world and this has paved the way to innovative a digitalized financial system which is now known as Fintech solutions.

2.2 Objectives of the study

- To explore the fintech landscape of India and its key growth drivers
- To investigate the fintech driven financial innovation in the country
- To examine the relationship between fintech growth and financial innovation in India
- To evaluate the future of financial innovation in relation to growth of Fintech.

3. Methodology

A mixed design has been used in the study which involves using both quantitative and qualitative data for the research. Qualitative data is referred to as textual or non-numerical information while quantitative data is referred to as numerical information (Kandel, 2020). Hence, both numerical and non-numerical information has been used in the research to provide a comprehensive account of the subject. On the other hand, a secondary method of data collection has been used in the research to collect both qualitative and quantitative information on the subject. The secondary method refers to collecting information from pre-existing sources that are made available to the public (Pandey & Pandey, 2021). Peer-reviewed journals, online articles,

government reports and statistical databases have been referred to for the collection of required data on the topic. The data available online on the development of the fintech industry and financial innovations have been collected for the last 5 years to perform the required analysis. On the other hand, the analysis of the entire collected data has been done in the forms of themes where multiple themes have been developed in the next section of the article to present the findings in a structured and organised manner. Further, the analysis of the quantitative data has been done with the help of MS Excel to understand the relationship between fintech and financial innovation. Correlation analysis have been done using MS Excel to assess the impact that fintech has had on financial innovation in the country.

3.1 Sample Details for Correlation Analysis

The correlation analysis was conducted using secondary data collected for a five-year period (2018–2022). The dataset consists of annual observations on fintech funding and selected indicators of financial innovation in India. Data were compiled from publicly available sources including Statista Research Department, EY India Fintech Report, NPCI reports, TRAI reports and other published government reports.

For the purpose of correlation analysis, the following five variables were considered:

- Funding of Fintech Start-ups (US\$ Billion)
- Digital Payments (US\$ Billion)
- Neo-banking (US\$ Billion)
- Digital Assets (US\$ Billion)
- Digital Investments (US\$ Billion)

The dataset comprised **five annual observations (n = 5)** corresponding to the years **2018, 2019, 2020, 2021 and 2022**. The collected data were entered into Microsoft Excel and Pearson's Correlation Coefficient was calculated using the Data Analysis ToolPak to examine the relationship between fintech growth and financial innovation indicators.

Pearson's Correlation Coefficient was used to measure the strength and direction of the linear relationship between fintech funding and selected financial innovation indicators. The coefficient value ranges from -1 to $+1$, where values closer to $+1$ indicate a strong positive relationship,

values closer to -1 indicate a strong negative relationship, and values near zero indicate little or no linear relationship. The analysis was performed using Microsoft Excel.

The impact of Fintech services on the Indian financial market cannot be ignored in the current era. Due to the presence of an opportunistic landscape in India, the number of participants in the Unicorn events has also increased over the prior years. For example, Paytm and Policy Bazaar were the sole participants in the Unicorn Event of 2018, which has increased over time. According to the latest findings, around 24 unicorn companies have been acknowledged as a part of India's Fintech market (Assets. ey, 2022). This can further be linked with the identified change in Global Fintech aspects which have influenced the Fintech market of India. In other words, an alignment between the Global market and the Indian Fintech market can be observed which can be considered as a core reason behind India's stable growth in Fintech services. Studies have also suggested that India has acquired a top place in the list of Asia-PACific countries with an investment of \$7.8 billion in 2021.

India's current situation can be considered useful whereas investment in Fintech services can be considered beneficial for achieving economic growth. Several financial studies have been conducted over the prior years which have illustrated India as the third largest market for Fintech services (Assets.ey, 2022). An approximation has also been made which has depicted an achievement of 10x growth in the upcoming years.

The reason behind this type of high scope can be linked to the availability of high-speed internet, high-tech devices and others. According to financial calculations, the Fintech market of India is hoped to achieve an astonishing amount of \$200 billion in revenues and \$1 trillion in AUM. The outbreak of the pandemic can also be considered the key driver for the Fintech industry's high scope in the Indian market which has acted as an instigator for digital adoption. In other words, the pandemic outbreak in India has made the adoption of digital technologies a mandatory aspect.

4. Findings and results

4.1 Fintech landscape of India

Year	Unicorn event by year (24)
As of July 2022 (9)	         CoinSwitch MobiKwik Slice BharatPe Acko Yubi Onecard Open (Formerly Ofbusiness)
2021 (7)	       Cred Chargebee Digit Groww Zeta CoinDCX Upstox
2020 (3)	   Razorpay Zerodha Pine Labs
2019 (3)	   Razorpay Billdesk Zoho
Upto 2018 (2)	  Paytm Policy Bazaar

Figure 1: Fintech Unicorn Event in India

(Source: Assets.ey, 2022)



Figure 2: Fintech Funding

(Source: Assets.ey, 2022)

The high scope for Fintech growth in the Indian market can further be observed through its stages of investments along with the number of rounds. According to financial analysis, the amount of investment in the Fintech market of India was around \$1.9 billion which has faced an astonishing growth of \$3.9 billion (Assets. ey, 2022). A sudden decrease in 2020, can be observed which amounted to \$ 2.9 billion in terms of Fintech funding. This amount has achieved significant growth in 2021, which can be depicted through a high rate of investment.

The amount of Fintech funding in 2021 was \$ 7.8

billion which can be considered as the highest investment to date. The fluctuation in the Fintech funding statistics can be reasoned with the ongoing pandemic issues and other circumstantial events. According to statistical data, around 5.4% of the Fintech funding denotes their focus on Cryptocurrency and Blockchain and 44.4% of funding denotes some form of online payment system (Assets.ey, 2022). The rest of the function can be divided among other critical aspects such as Neo-banking, Insurance tech and other forms of Fintech services.

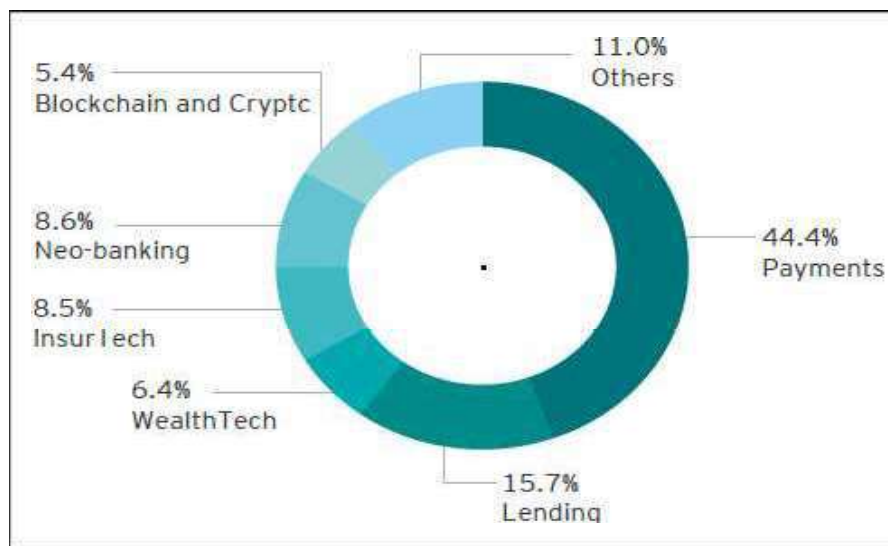


Figure 3: Fintech funding percentage

(Source: Assets.ey, 2022)

4.2 Key growth drivers of Indian Fintech

The presence of high opportunity in the Indian Fintech market can be aligned with the identified growth rate of Fintech investments. Access to adequate financial support along with appropriate regulatory stance can be considered as a positive business environment which can be considered as a key driver of Indian Fintech services. The growing economic structure of India can be addressed as useful for firms looking forward to investing in Fintech services. According to Bau & Matray (2023), the government of India's decision to provide automatic approval in "Foreign Direct Investment " can be reasoned with its access to foreign capital. In other words, access to foreign capital can also be lined with the growing trend in the Indian market which denotes a high scope for Fintech services.

Adoption of modern technology can also be portrayed as a positive factor that can complement the inclination towards Fintech investment. The government of India's inclination towards investment in modern technologies can also be considered as a key driver which has allowed the Indian Fintech market to acquire significant boost in the current period. As per the findings, the investment in information and technology was around 91 billion U.S. dollars in 2021 which has faced an increase in the current era (Sun, 2022). An estimation has also been made which illustrates an amount of 111 billion U.S. dollars worth of investment in 2024. Apart from that, the availability of a skilled workforce can also be addressed as a key driver of the Fintech market in India.

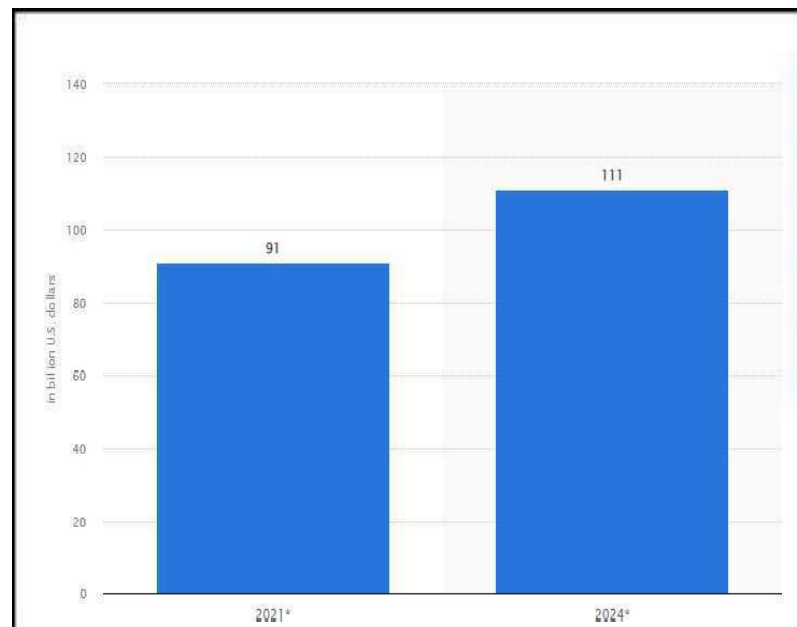


Figure 4: ICT valuation in India

(Source: Sun, 2022)

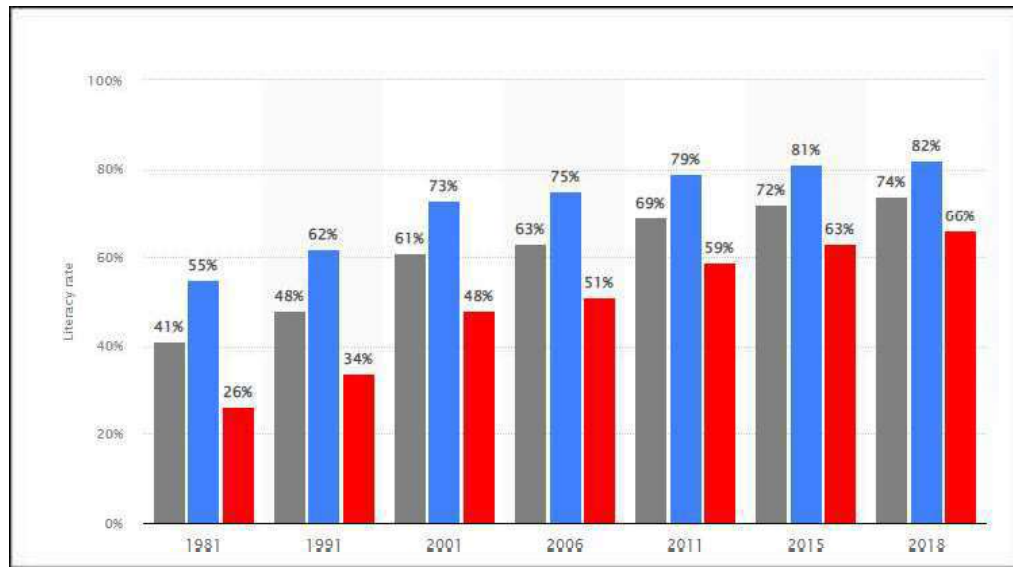


Figure 5: Literacy rate in India

(Source: O'Neill, 2023)

According to recent studies, a stable growth rate in the Indian literacy rate can be observed. For example, the literacy rate among men in India was 55% in 2018 and the female literacy rate was 26%. The current analysis also depicts around 82% literacy rate among men and 66% literacy rate among women (O'Neill, 2023). Hence, the increasing literacy rate in India can be considered beneficial for the Fintech market where a high rate of investment seems a beneficial aspect. India's inclination towards mobile devices can also be considered a sign of high scope in terms of Fintech services. For example, the number of wireless subscribers in India was 1038.45 million (Trai.gov.in, 2023). It can further be acknowledged as a key driver of Fintech investment.

4.3 Fintech driven financial innovation in India

The higher investment in the Fintech industry can also be aligned with the rise of innovative measurements and approaches. For example, digital adaptation in India can be displayed through the rising number of internet users, mobile users, internet users from rural areas and others. Studies have suggested that around 47% of the population of India between the age group of 16 to 64 is known for using the internet on a daily basis (Assets. ey, 2022). The amount of mobile penetration rate is 81% which can be considered

adequate. Several surveys have also been conducted which illustrated that the percentage of mobile internet users is around 91%. According to findings, the number of rural internet users in 2021 was 352 million. Apart from that, the number of users in urban areas is 294 million which can be considered as an appropriate scope for investing in Fintech.

UPI development can also be considered as a part of innovative measurements that can be linked with the investment in Fintech services. The usage of UPI or "Unified Payments Interface" can be observed in the payment system of India (Npci.org.in, 2023). This has allowed the majority of the Fintech users in India to indulge in online payment activities. The beneficial aspect of the digital payment system can be portrayed through the minimisation of transaction costs which can be observed in the regular banking services. The technological landscape of India can also be insured as a beneficial outcome where critical and useful aspects such as Aadhar, Jan Dhan, and mobile usage can be addressed as major contributions (Pib.gov.in, 2023). According to a survey, India is known for having around 800 million mobile phone users which has further supported the growth of the Fintech industry. These types of approaches can further be considered as public infrastructure representing the digitalisation aspect in India.

4.4 Impact of Fintech on financial innovation in India

Table 1: Fintech and financial innovation in India (2018-2022)

Year	Funding of fintech start-ups (in billions \$)	Digital payments (in billions \$)	Neo-banking (in billions \$)	Digital Assets (in billions \$)	Digital Investments (in billions \$)
2018	1.6	54.29	4.39	11.56	109.8
2019	2.8	71.21	9.4	9.58	187.1
2020	2.2	96.41	18.56	38.7	247.8
2021	8	130.5	34.67	216	422.9
2022	4.2	153.3	53.6	145.8	589

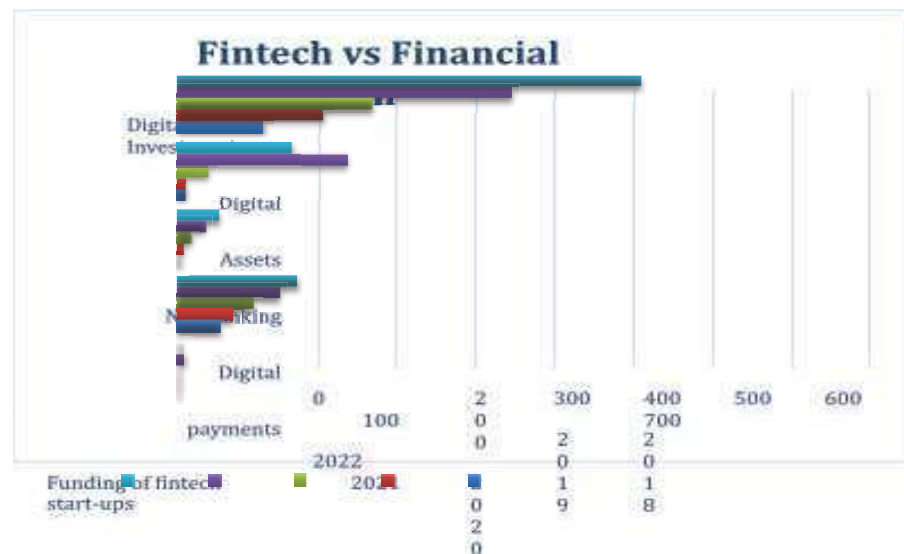


Figure 6: Graph depicting the trends in financial innovation and fintech in India over the past five years (2018-22)

(Source: Self-developed using data from Statista Research Department)

Based on the above data, it is visible that digital assets, payments, neo-banking and digital investments have continuously grown over the years in India. The fundings to Fintech start-ups has also more than doubled in the last five years

from \$1.6 billion in 2018 to \$4.2 billion in 2022. Hence, the relationship between the growth of fintech and financial innovation has further been studied with the help of correlation analysis and the results of which have been provided below.

Table 2: Correlation analysis

	<i>Funding of fintech start-ups</i>	<i>Digital payments</i>	<i>Neo-banking</i>	<i>Digital Assets</i>	<i>Digital Investments</i>
Funding of fintech start-ups	1				
Digital payments	0.679939731	1			
Neo-banking	0.598238386	0.984183	1		
Digital Assets	0.937189335	0.856238	0.806976	1	
Digital Investments	0.63085929	0.986305	0.997738	0.820728	1

Based on the results of the correlation analysis it can be established that there is a positive relationship between fintech and elements of financial innovation like digital payments, digital assets, neo-banking and digital investments. The relationship is also strong between the variables since the co-efficient value is more than 0.5 or 50%. Hence, the impact of fintech has been significant on financial innovation in India since there is a strong positive relationship between the two elements.

4.5 Fintech and the future of financial innovation in India

The growing demand for digital innovation has led to higher maturity of the Fintech industry of India, fintech can be seen as an umbrella term which includes technology-enabled financial services that contribute to improving the business models of the organisation. The payment companies in particular are particularly the most important as they help in providing online payment solutions through mobile wallets and different digital gateway methods. The fintech companies are also infamous for lending companies to develop their digital solutions. Insurance and investment companies also benefit from this innovation as they are able to manage funds and provide insurance digitally to people. Fintech is deeply rooted in everyday economic transactions. In research carried out on fintech adoption, it has been found that around 84% of the surveyed participants were well aware of fintech

services and around 20% use at least two fintech services (Mention, 2019). Firms across India have recognized the potential which financial innovation provides to organisations and its contributions to helping startup organisations prosper.

The increase in fintech technology shows the capability of the Indian technological sectors, the companies in the Indian financial sectors can provide personalised customer-centric services to the people through this method. It has been observed that the investments in the Fintech technologies of India have also increased with time, in 2013, investments in these emerging technologies were observed to be \$12.2 billion, however by the year 2018 the investments raised by the top fintech industries had been around \$31.85 billion. Globally it has been observed that the investments have been around \$31.85 billion (Mention, 2019). It should be mentioned that the growth of the fintech sector has been due to a number of factors, the growth in capital income of people, broader financial inclusivity and larger access to internet connection across India have contributed to this growth, and the Indian Fintech sector is expected to grow further.

5. Discussion

The Fintech industry can be considered as a rising factor which can be observed in the global market. Bhatnagar et al. (2022) have also illustrated that India is often considered a Fintech hub in the global market. In other words, the Indian market can be

considered as a feasible option where investment can be made in the Fintech services. Reasons such as these can further be linked with the increasing demand towards technological adaptation. The rising amount of the ICT market can also be aligned with the Indian market's capability to invest in Fintech services. For example, the rising number of investments in Fintech services can be addressed as an attribute of India's emerging market. In other words, the landscape of India in terms of Fintech services has illustrated a high scope for investing in Fintech services. The rising number of innovative measurements can also be considered as the outcome of significant investment in Fintech services which have allowed the Indian market to reach a higher success rate.

The presence of an adequate business environment can be addressed as a major driver for the Fintech market which denotes availability of capital support. The Indian government's automation of FDI approval can be linked with this outcome which has allowed India to achieve higher financial support for fulfilling necessary goals. The increasing literacy rate can also be considered as a major driver which has allowed Fintech services in India to achieve a high success rate. Gautam et al. (2022) have also illustrated a robust connection between digital literacy and Fintech integration. Hence, it can be addressed that the Indian market denotes a high scope for investment which can ensure the successful integration of Fintech services.

5.1 Comparative Discussion with Previous Literature

The findings of the present study are consistent with earlier research on fintech and financial innovation in India. The Pearson correlation analysis revealed a strong positive relationship between fintech funding and indicators of financial innovation, including digital payments, digital assets, neo-banking and digital investments. These findings support the observations of Goldstein et al. (2019), who argued that fintech serves as a catalyst for financial innovation through the adoption of digital technologies. Similarly, Gupta and Agrawal (2021) reported that the rapid expansion of fintech in India has significantly accelerated digital financial services and improved financial accessibility. The present findings also align with Rastogi et al. (2021), who highlighted the transformative role of the Unified Payments Interface (UPI) in strengthening digital payment adoption and promoting financial inclusion.

Furthermore, the results are consistent with the work of Rupeika-Apoga, R. (2022). which identified fintech as a key driver of technological innovation and future growth in the global financial sector. Although the present study confirms these earlier findings, it is based on secondary data covering only five annual observations (2018–2022). Therefore, while the observed positive relationships are in agreement with previous literature, future research using larger datasets and more advanced statistical techniques such as multiple regression or panel data analysis would provide stronger empirical evidence.

6. Conclusion

The core aim of this study is to demonstrate the impact of Fintech innovation on the Indian market. The overall findings of this study have demonstrated that the Indian market is known for having an appropriate market situation that can ensure successful investment and outcome through Fintech integration. The volatile nature of the modern market and rising complexities in the economic structure can also be considered as the foremost reason which has made it necessary for the modern South to focus on Fintech investment. The limitation of this study can be portrayed in the usage of secondary data. Including primary data can be considered as a feasible approach that can enhance the quality of the outcomes.

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PredictGuard: Multi-Horizon Fall Risk Prediction with Personalized Baseline Learning for Privacy-Preserving Elderly Care

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ABSTRACT

Falls are the big reason for injuries among elderly people which requires consistent monitoring and immediate attention from care givers to prevent mishaps. In this work, PredictGuard is developed as a wearable fall prediction system which uses data from inertial sensors and processes it using edge intelligence to predict fall risk and alert care givers to take immediate actions. Most existing fall detection systems react only after a fall happens, but our system estimates and predicts the falling risk along multiple axes and categorises risks as immediate, short-term and long-term risks while also preserving the privacy of each individual.

The system understands the normal walking features from the data collected from the IMU (Inertial Measurement Unit) and sends this to an AI model (deployed on edge) to process it and predict fall risks for immediate, near-future, and long-term time periods. The system first learns the walking pattern of a particular individual then later if the system notices a change in pattern or instability in walking pattern it generates a fall risk alert. The system was tested in practical environments as well as on standard available datasets. It delivered 98% accuracy for different categories of fall risks.

The model is simple enough to run on edge devices with limited resources, while still giving good performance and maintaining privacy of users on the system (edge processor). Because of this, the system can be used for a larger number of users in healthcare and helps monitor elderly people by predicting fall risk before an actual fall happens.

I. INTRODUCTION

Falls are one of the major health risks for elderly people around the world. This may result in various health issues including the fractures, skull injuries, tendon/ligament twisting or breaking affecting the lives of elderly people and people around them. Along with the physical injuries these falls might have severe psychological impact on individuals such as fear of falling which may lead to reduced mobility activities of people which again might lead to different health disorders. As we know the world population is aging with time the elderly individuals keep increasing the requirement and dependability on reliable fall monitoring systems keep growing. Thus scalable and efficient fall monitoring systems become a necessity of upcoming world.

The fall detection system available in today's market, they basically react to falls and send alerts once the users actually fall. This might cause delay in getting help from the care givers and might pose a potential risk because of this delay in alert. But our framework predicts the mishap before it actually happens leading to early alerts and categorization of upcoming risks helping to be prepared for upcoming events. Thus resulting in better overall preparedness for what possibly can happen. The existing approaches include wearable systems and vision based monitoring. In wearable systems they basically make decisions with reference to some fixed value (threshold) whereas the vision based system relies on cameras to detect the falls. The threshold based system though they perform really well in controlled environment are often prone to false alarm during normal activities in practical environment. The vision based system raises the privacy concerns and is often affected by positioning of camera and ambient light. Thus the focus has shifted from systems detecting the falls to systems predicting the falls. That is from reactive to proactive fall monitoring. Where early signs of instability and imbalance which might lead to fall are studied and analysed. These early signs or indicators are characterized by studying the patterns in the walking mechanism of people. It focuses on identifying length of steps, the front back and sidesways movements and the motion stability. However still the gap remains as the current methods do not account for classification of risks with respect to time,

personalised support and maintaining the privacy. Also deployment of this existing methodologies in real environment where resources are limited for edge deployment still remains a challenge.

To account for these limitations our proposed model PredictGuard focuses on giving the personalized base model for each individual and preserving the privacy and reducing false trues in real world applications. Based on the data received from the IMU a deep neural network predicts the fall risk and categorizes it in classes immediate, short-term and long-term risks. Along with it a personalised model studying individual walking patterns and detecting the deviations leading to instability.

The main focus of this work is to develop a smart fall-risk prediction system for elderly care using wearable sensor data and edge AI. The main goal of PredictGuard is to build a smart fall-risk prediction system using wearable sensors and edge AI. The model predicts risk across multiple time periods and uses a multi-task neural network for classification. Along with that it also learns the normal walking pattern of each individual, helping reduce false alarms. And since the model runs locally on edge devices, it supports real-time prediction and also preserves privacy.

The rest of the paper is as follows. Section II discusses existing research in this area. Section III explains the overall system design, Section IV describes the prediction model, Section V presents the experimental results, and Section VI covers clinical validation along with future scope.

II. RELATED WORK

Recent studies in wearable sensing devices and AI and machine learning has led to development of an automated fall monitoring system for elderly people. The existing methodologies in this domain consist of wearable sensor monitoring, vision based monitoring systems, multimodal/combinational methods and edge deployable smart systems. All of these have their own pros and cons leading to development of an all round solution which is proposed by our solution.

A. Vision-Based Fall Detection

It uses the RGB cameras for 2D mapping while AI for calculating and monitoring posture changes and readings of skeleton. Or it might use depth cameras

for calculating the distances along z axis using IR rays distortion pattern and making a 3d map. These are very useful in analysing the human posture and helping understand patterns in motion. The accuracy of this system is pretty high in lab conditions as photos from the rgb and depth cameras can provide spatial information.

But their deployment in real world remains questionable because of privacy risks it poses inherently. Also this system's dependability and sensitivity to ambient light conditions makes its practical implementation harder. On top of that this system is also very much dependent on positioning of cameras, the maintenance of which becomes much more challenging with elderly people. As a result the continuous video monitoring becomes unsuitable for households and healthcare places.

B. Wearable IMU-Based Systems

The wearable IMU being portable, cheap and highly accurate came out to be as the better alternative to vision based system. And if the data from IMU is being processed at edge to make decisions it provided high level of privacy by not exposing the data to internet. This system reads the data from accelerometer and gyroscope to detect the abnormal motion patterns causing falls. although many studies show that threshold based and machine learning techniques provide high accuracy but most of the methods are limited to only fall detection after they happen. Also differentiating the falls and some high intensity daily activities remains a challenge often causing false positives.

C. Multimodal Sensing Approaches

To make the system sturdy studies often find out that combining one or more methods might be helpful to get best of both worlds. This includes combining the wearable sensors with the thermal

cameras or pressure sensors or any other ambience monitoring device. Even though multimodal approach can improve the performance, it does increase complexity of system, the system becomes more expensive and also affects the energy consumption. And if it is incorporated with vision based detection then privacy issues still remain unresolved.

D. Edge-Based Intelligent Systems

The shift of computation from cloud to edge devices led to deployment of ML models on edge devices rather than cloud platforms. Cloud contributes to training of the models while deployment is done on edge. This edge processing provides several benefits such as less latency, more privacy, improved processing for a particular task and real time results. But for this deployment simple neural networks are preferred because of limitation of resources. Still most of the existing devices are only doing the detection on edge devices rather than utilizing full extent to predict the falls.

E. Research Gap

Even though fall monitoring systems have improved over time, there are still some important problems. Most existing systems only detect a fall after it has already happened, instead of warning before it occurs. Also, many of these systems do not consider that every person has a different walking pattern, so using the same reference for everyone can reduce accuracy. Another challenge in this was the running these models efficiently on edge devices where resources are limited. To solve these problem, PredictGuard uses wearable sensors and a deep learning model to predict fall risk early and also learns the normal movement pattern of each individual and maintaining user privacy.

TABLE I
COMPARISON OF EXISTING FALL MONITORING APPROACHES

Approach	Sensor Type	ML Model	Prediction	Edge Deployable	Personalization
Vision-based	Camera	CNN	No	No	No
IMU-based	Wearable	Threshold/ML	No	Yes	No
Thermal + IMU	Hybrid	ML	No	Yes	Limited
Vision + IMU Fusion	Hybrid	Deep Learning	No	Partial	No
Edge ML Systems	Wearable	Lightweight NN	No	Yes	No
PredictGuard (Proposed)	IMU	Multi-task DNN	Yes	Yes	Yes

Kalyani Bokade & Kalpana Thakre 'PredictGuard: Multi-Horizon Fall Risk Prediction with Personalized Baseline Learning for Privacy-Preserving Elderly Care'

III. SYSTEM ARCHITECTURE

Here we have put together all the 5 different pieces in our system: sensing, processing the signal, extracting the features, a multitasking model, and a layer for making the decisions regarding the prediction at the end. Figure 1 shows how they are all connected.

Privacy was our main concern while designing the model, so we focused on processing the data and

performing predictions locally on the device in real time. Movements of users are detected by the sensors that users are wearing. These movements are then cleaned to convert them into walking-related movement data to feed to our neural network. The model works on the cleaned data. The unfiltered data is cleaned first before giving it to the model, so the model only works on cleaned data.

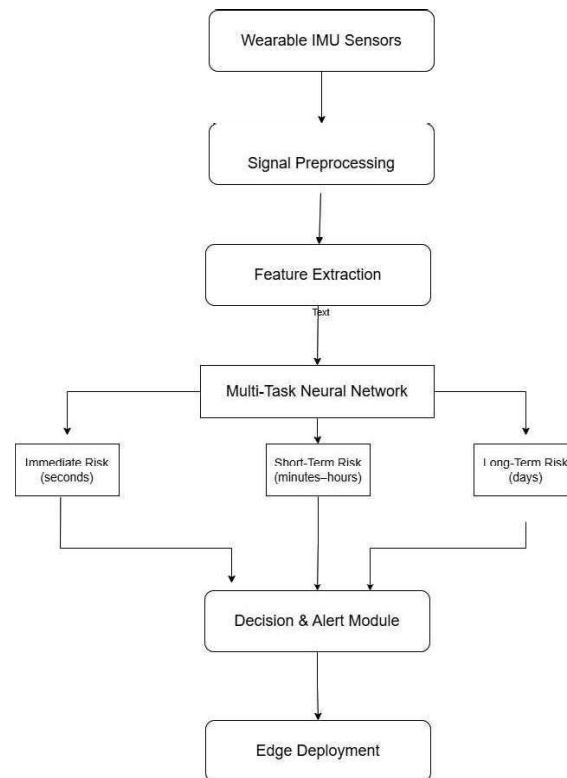


Fig. 1. Overall architecture of the PredictGuard system.

In the beginning, the movements are sensed. This is done via the wearable IMU, which itself consists of an accelerometer and gyroscope, with three axes on both. They capture the linear acceleration and angular velocity as someone walks. Now the position where we place this sensor is crucial. We generally put it around the waist or on the wrist because these are the 2 best positions to get the movement data of users. We set the sampling frequency to 50 Hz because at this rate we can get the important movement data without compromising the power requirements. At this rate,

we can maintain the balance between battery life and the data we want to collect.

The original signals we get through the sensors are not of any use to our model directly because they are distorted due to noise and are not well structured for the model to process yet. Figure 2 shows how data cleaning is done and noise is filtered out. The filtered signal is divided into small parts (here referred to as windows). Each window is analysed by the model to retrieve patterns related to instability which may lead to a fall. These instabilities might be variation in step length,

asymmetry in posture, the rhythm of movements, or stability in movements. Now the extracted signals show a few seconds of walking duration.

These are combined into a single vector which consists of all the features. This vector serves as input to our prediction model.

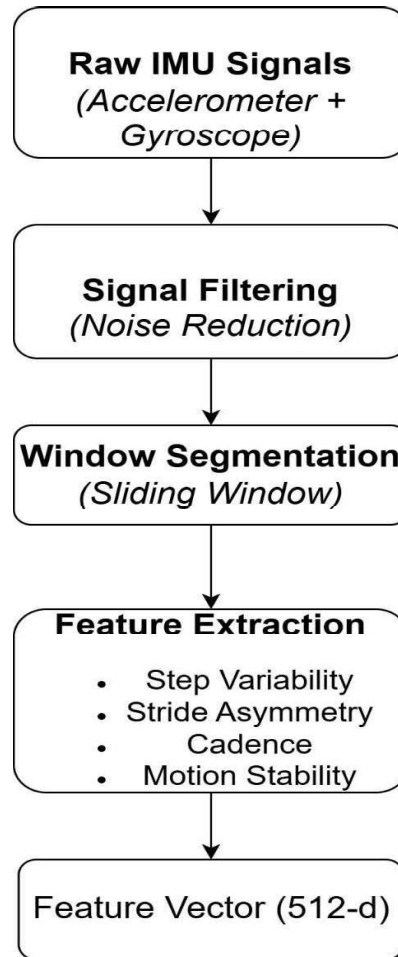


Fig. 2. IMU signal preprocessing and biomechanical feature extraction pipeline.

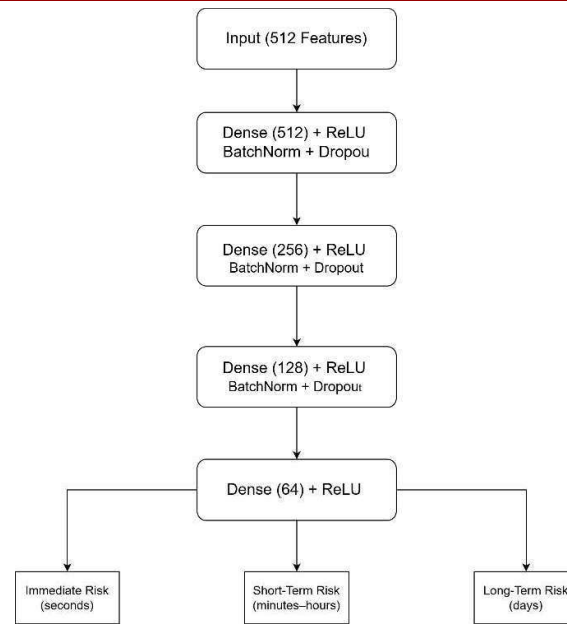


Fig. 3. Neural network architecture of PredictGuard.

The feature vector is then processed by the deep neural network with an encoder and multiple output heads, where the heads represent prediction horizons (immediate, short, and long term). Figure 3 shows this exact architecture. The shared encoder learns the difference between normal and unsteady walking patterns that are then generalized for all the three horizons. The shared representation is then used by different output layers to predict risks and classify them on their own. This architecture enables the model to independently predict each horizon while avoiding complex computations by running all in one model instead of three.

False alarms are another major problem with existing models. To reduce them, we implemented a customised baseline learning model. The first step, as usual, is calibration, when the system learns normal walking patterns and related motions. For this, the system relies on data collected from the sensors. Once this is done, all the feature vectors are compared with the baseline instead of generic average values calculated as used in other models. Whenever the model notices drift from the original baseline values, like walking getting less steady than usual, then it is noticed by the system. The baseline is updated periodically because mobility can change over time, and older baseline data may not accurately reflect the user's current

walking pattern.

The risk scores generated across the drifts the system notices are finally converted into executable actions. This is done in the final stage. These calculated scores are then compared with the threshold values, and the action taken next depends on the category of risk generated. For immediate risks (high risks), a real-time alert goes directly to caregivers. For short- or long-term risks, different actions are taken where users are notified regarding the activity and recommended to change the course of activity. It also asks users for closer monitoring and tells them to stop doing their current work and get support or any kind of help before the next 10 seconds. Its whole point is to act before the fall.

One of our main design focuses was designing it to be hardware compatible. The whole pipeline was built keeping the hardware it works on in mind. We built a network that is small but fast and consumes less power to make it memory and power efficient. We did the computation entirely on the edge device instead of the cloud. Thus, not only do we preserve users' privacy, but we also reduce the latency of the system for real-world applications. All this made real-time monitoring deployable in the real world rather than only in laboratory environments.

IV. IMPLEMENTATION

Fall risk prediction on wearable devices involves balancing prediction accuracy with computational efficiency. Heavy models are difficult to run on limited hardware. But we solved this problem in PredictGuard.

Here, instead of predicting one thing on one model, we divided the problem into three different categories: immediate, short-term, and long-term, called three time horizons. It handles all three of these via a single backbone shared between them. Instead of running three separate models, we share the same backbone between the three time horizons. This reduces the need for complex computation because the edge device has limited resources, so running three different models is not a realistic approach. So we overcome this by using small output heads sitting on top of a shared encoder between them.

As we know, the raw IMU readings are filtered and converted into a vector of features where each sample is represented by 512 numerical values describing walking patterns and movement statistics. These feature vectors are converted into a standard form before they are given to the network so that dimensions with larger numerical ranges do not suppress the others in the training process.

The encoder takes that 512-dimensional vector and compresses it by passing it through 4 dense layers where each layer is smaller than the previous layer. The network includes standard components such as normalization, dropout, and non-linear activation functions. An important consideration during design was the number of layers and the gradual reduction in layer width. This reduces the complexity of computation by keeping the data size small to run on limited hardware on the edge device.

On the output side, three heads sit on the encoder's output h as:

$$y_{\text{imm}} = \text{softmax}(W_1h + b_1)$$

$$y_{\text{short}} = \text{softmax}(W_2h + b_2)$$

$$y_{\text{long}} = \text{softmax}(W_3h + b_3)$$

Model training uses a weighted loss function given by

$$L = \alpha L_{\text{imm}} + \beta L_{\text{short}} + \gamma L_{\text{long}},$$

where the weights are 0.5, 0.3, and 0.2, respectively. A higher weight is assigned to immediate risk since it is the most critical for real-time intervention, while short-term and long-term risks continue to contribute to learning in

the shared encoder. Another challenge we faced was improper labeling of data. The data came with only one label per sample, not three as we require here. So before the system implementation, we had to fix this. The labeling needed to be done for the remaining two horizons. The original labels are used for the immediate labels as they are. Short-term labels are generated using information from neighboring samples to capture short-duration trends. Long-term labels are generated using cumulative risk propagation so that the model can track gradual risk drift over time instead of relying on data at any particular instant.

The model was trained using the Adam optimizer with a learning rate of 0.001 and a batch size of 64. The whole training was completed within 60 epochs to prevent overfitting, which might cause deviation from laboratory results during real-time application.

As the end result of all this, when the model is finally deployed, each new feature passes through the whole network in real time. This helps us obtain three risk estimates at once: immediate, short-term, and long-term. That's the advantage here, achieved by splitting the prediction into three horizons instead of using a separate model for each horizon.

V. EXPERIMENTAL EVALUATION

The performance of proposed predictguard system is determined using reference datasets, real time performance analysis, ablation studies, and deployment metrics.

A. Datasets and Evaluation Protocol

Testing of our PredictGuard model, like the other models, involved covering two very different scenarios. One is the clean benchmark data under laboratory conditions, while the other is unpredictable, noisy, and real-world implementation data. We used this to precisely measure the transition from laboratory to practical performance.

During the training and laboratory testing phase, three datasets were mainly used: SisFall, MobiAct, and CAUCA-FALL. SisFall is the largest dataset of the three. It consists of more than 4500 sequences of motion ranging from young adults to elderly people as participants. The MobiAct dataset is the middle ground of the other two datasets, where it

consists of almost 2000 recordings in total. Out of those, only 200 were related to falling conditions, and the rest were everyday movements. The CAUCA-FALL dataset is even smaller, consisting of only 1200 readings from falls and regular activities collected from 30 participants.

Real-world evaluation was carried out over a period of 6 months at three elderly care facilities in Maharashtra, India. The study included 35 participants with an age of 74.2 ± 6.8 years. During the monitoring period, the system confirmed 42 cases of falls and 187 near-fall events. We got them verified by the staff and clinicians. Data was collected under real-life conditions, consisting of

residential areas, staircases, bathrooms, nighttime activities, and outdoor environments.

The evaluation was done in two stages. First, the benchmark datasets were evaluated using 5-fold cross-validation to evaluate the model's generalization performance. The second stage used real-world deployment data by training the model on data collected during the initial implementation period and evaluating it on the subsequently collected data. The performance of the system was assessed using accuracy, precision, recall, F1-score, AUC-ROC, false alarm rate, and early prediction lead time.

B. Baseline Comparison

TABLE II
COMPARISON OF FALL MONITORING APPROACHES

Method	Lab Accuracy	Real Accuracy	Privacy	Edge Deployment	Prediction Capability
Vision-based	99.2%	57%	Poor	No	No
IMU-based	97.9%	75%	Good	Yes	No
Thermal + IMU	96.0%	92%	Excellent	Yes	No
Vision + IMU Fusion	99.0%	96%	Fair	Partial	No
Edge Transformer	95.0%	88%	Good	Yes	No
PredictGuard (Proposed)	99.0%	96.4%	Excellent	Yes	Yes

Table II compares PredictGuard with the existing approaches, considering both the laboratory and real-world conditions. Our proposed framework achieved 96.4% real-world accuracy while also maintaining privacy and low computational overhead through edge processing.

The results shown in Table II and Fig. 4 indicate that most existing approaches perform well under

laboratory conditions, but their accuracy decreases when tested in practical environments. On the other hand, PredictGuard showed only a very small drop in performance when comparing laboratory and practical results. All this suggests that the proposed model can work effectively in real-world conditions rather than only in laboratory environments.

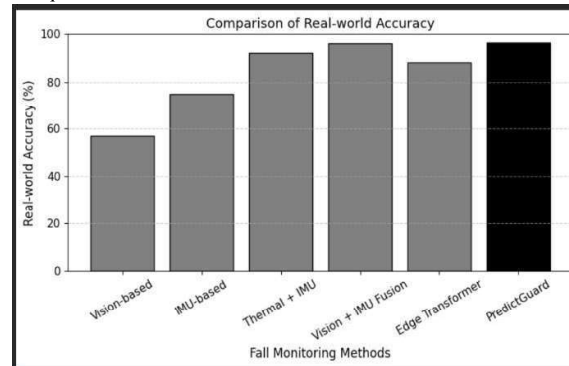


Fig. 4. Real-world accuracy comparison of fall monitoring systems.

C. Results and Classification Analysis

The performance of our system was steady and accurate across all three horizons (immediate, short-term, and long-term), along with high precision and solid scores during the whole testing period. Figure 5 describes the confusion matrices for each horizon. This is also the point where specific weak spots can be identified.

The immediate and long-term prediction tasks achieved high classification performance with relatively few misclassifications. The short-term

prediction task showed slightly lower performance, primarily due to class imbalance introduced during the label generation process, which reduced the number of training samples available for some minority classes. Despite this limitation, the overall performance of the model remained consistent across all prediction horizons, indicating that the shared encoder was able to learn effective representations without favoring any single prediction task.

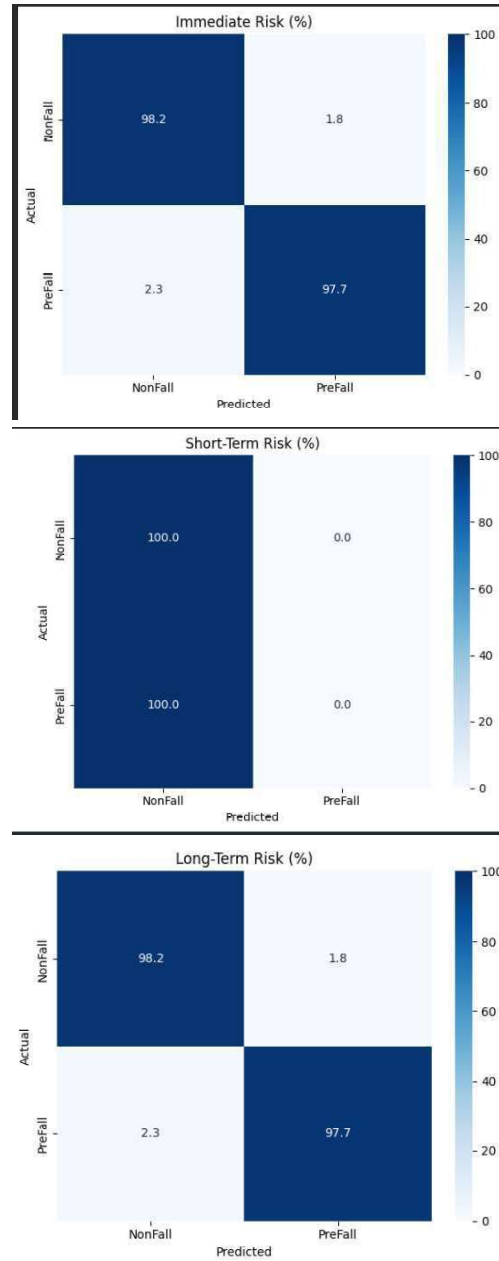


Fig. 5. Confusion matrices for fall risk prediction.

D. Ablation Study

TABLE III
SENSOR CONFIGURATION ABLATION RESULTS

Configuration	Lab F1	Real F1
IMU only	95.2%	89.4%
IMU + Pressure	96.8%	92.1%
IMU + Thermal	97.5%	94.3%
Full system	98.9%	96.4%

The ablation study was performed to understand the contribution of each sensor configuration to the overall performance of the system. Table III represents the IMU-only configuration, which provided good performance in the laboratory as well as in the real world. However, combining additional sensors improved the F1-score further, and the complete system achieved the highest performance among all evaluated configurations.

Table IV represents the effect of customised baseline learning on the performance of the system. After incorporating the personalised baseline, the false alarm rate decreased drastically from 8.1 to 2 per week. Also, the sensitivity improved from 92% to 94% after implementing the personalised baseline model. This shows that when the model adapts to an individual user's normal walking pattern, it improves prediction accuracy and the overall reliability of the system.

TABLE IV
IMPACT OF PERSONALIZED BASELINE LEARNING

Model Type	False Alarms / week	Sensitivity
Population model	8.1	92%
Personalized model	2.0	94%

E. Real-World Performance Analysis

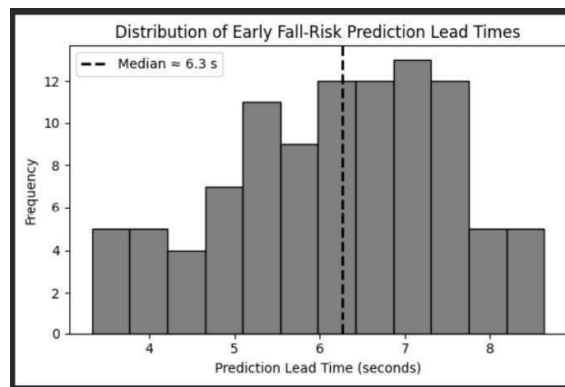


Fig. 6. Early fall-risk prediction lead times.

Table V shows the performance in different environments, including daytime living spaces, nighttime conditions, bathrooms, and outdoor environments, covering almost all situations where instability might occur during walking or normal activities. We achieved an accuracy of 96.4% across these different environments. False alarms were not generated even when the surroundings changed. One more important thing discussed here is timing.

Figure 6 tracks how early alerts were generated compared with when the actual event occurred. Many high-risk situations were notified several seconds before anything actually happened. On average, notifications were generated roughly 6.3 seconds before the actual event. That might not be a huge window, but it is sufficient for caregivers to take early action and also for users to prepare for upcoming mishaps by grabbing support, slowing their movement, and preparing themselves.

TABLE V
REAL-WORLD PERFORMANCE ACROSS ENVIRONMENTS

Environment	Accuracy	False Alarm Rate
Daytime living areas	97.8%	1.2/week
Nighttime	95.2%	1.8/week
Bathrooms	94.1%	2.1/week
Outdoors	93.7%	2.4/week
Overall	96.4%	2.0/week

F. Edge Deployment Performance

The edge deployment performance of the proposed framework is summarised in Table VI. The model size is 37 KB, with an inference latency of 35 ms and low power consumption, making it suitable for continuous operation on wearable devices. The small model size and low computational requirements enabled efficient deployment on resource-constrained edge hardware.

TABLE VI
EDGE DEPLOYMENT PERFORMANCE METRICS

Metric	Value
Model Size	37 KB
Inference Latency	35 ms
Power Consumption	8.2 mW
Battery Life	12 days

implementation performance as it focuses on the key limitations of existing fall monitoring methods. As we can observe in the figure 4 our system decreases the gap in laboratory performance and real world performance by training the model on large amount of data set collected from a huge pool of people. where the existing solutions show degradation in lab and practical implementation of nearly 15% to 42%, our proposed system, the PredictGuard has only 2.5% gap in performance from lab to practical use cases. This improved performance points to the strong resilience of our systems against the others. The better performance of our solution comes from analyzing walking patterns and learning the usual movement behavior of each individual.

As our ML model is deployed on edge all decisions are taken at edge so data of users is not exposed to the internet thus preventing it from being fallen in wrong hands. Thus by this edge deployment high privacy can be achieved while maintaining the real time processing functionality of system.

The use of IMU sensor data instead of RGB video analysis or depth camera video processing privacy is improved multifold. Along with this the systems

VI. CLINICAL VALIDATION

A. Clinical Validation

The proposed system shows high practical

ability to generate the early alerts and proper categorization of risk leads to proper precautionary actions being taken early thus saving the time during mishappenings. As shown in Fig. 6, the system is able to generate alerts a few seconds before a person loses balance, giving enough time to take preventive actions such as slowing down or seeking support.

B. User Acceptance Study

While the real time application of the system, a user study involving 35 elderly people showed the usability and excellent comfort levels of our system. 32 out of total 35 individuals found our device comfortable for regular day to day activities and almost 30 of them agreed that the system was not interfering with their routine work. Also 90% of users agreed with the alerts generated by our system thus winning their trust.

now for the caregivers we tested our system with 22 of them for their feedback. out of them 17 said the alerts generated are genuine and can be trusted, and also agreed that alerts were such that they get enough time to take required actions improving the overall efficiency. The consistent monitoring hours dropped from 4.2 to 1.4 hours daily according to them and false alarm rate 1 out of 10 giving our system a high accuracy trust of users.

C. Longitudinal Insights

Monitoring for long hours led to identification of behaviors which were clinically relevant. In many cases it is found that instability in walking pattern was because of effect of medication. Fatigue related instability was also observed during morning time. Linear decline in mobility with time was observed and later clinically confirmed. Along with this an improved stability in walking pattern was noted for patient taking physiotherapy treatments thus implying the systems capability to monitor recovery.

D. Intervention Effectiveness

The proposed system proved its effectiveness in getting the preventive measures early for at risk situations. A large number of immediate alerts generated helped users to take appropriate actions to stabilize and slow their movements or seek support nearby. In without intervention cases the obvious high fall rate was noted. The timely alerts of predictGuard resulted in reducing the fall rates.

The short term alerts helped to do adjustments during users' current activities and reducing their intensity during high risk periods contributing to overall well being of the users.

E. Ethical and Social Considerations

Ethics and user safety were given importance throughout this study. Every participant was informed about the purpose of the system and agreed to take part in the study. Proper care was taken to keep personal data safe and private. Participants were also free to stop using the system at any time if they wished. People from different age groups and backgrounds were included so that the study results would be more balanced and less biased.

VII. DISCUSSION

A. System Effectiveness

The proposed PredictGuard framework shows high practical effectiveness by overcoming the limitations of existing fall monitoring system. One of the huge upsides is the laboratory to real life implementation performance deviation of 2.6%, which is much lower than most of the existing methodologies. The better performance mainly comes from analyzing walking patterns and learning the normal movement behavior of each person.

The high privacy provided by the system further improves the real world implementation of the system for health care facilities and household use. By utilizing the edge based processing and non intrusive data from IMU the proposed framework reduces need of RGB or depth camera video monitoring. Along with this the early predictive nature of the system enables the timely intervention with alerts generated few seconds before the instability in motion of person so as to take the proper preventive measures.

Along with predicting fall risk, the model also explains the walking-related factors behind its prediction. This improves trust in the system. Also, because the model is small and efficient, it can be deployed on wearable edge devices without much difficulty.

B. Long-Term Stability

Long term steadiness is very crucial for continuous monitoring system. The customised baseline

learning model that is the model trained on personalised walking patterns of an individual adapts to physiological changes in walking patterns with time. While the system was deployed, it maintained stable performance, emphasizing on the adaptability of system on long run.

The system is designed in separate parts, so new sensors or features can be added later without changing the whole system. This makes future improvements easier while keeping the current model usable.

C. Limitations

Although the system is effective overall, there are still some limitations. One of the practical issues is that if the user does not wear the assisted device, it will not be able to detect the user during that time. Although there are backup systems that are able to record user activity when the user isn't wearing the assisted device, those systems' reliability is lower than when the assisted device is worn.

Another limitation of this technology is that fall-event data in the actual environment of the uncontrolled setting is not available. While it is known that falls do occur on a regular basis, actually collecting sufficient quantities of the data to use for training a machine learning model can be very time consuming. One possible solution to this problem would be to use simulated datasets or transfer learning.

A third limitation of the current system is that some users, particularly older adults with cognitive deficits, may struggle to respond to alert messages. A second limitation, which is actually related to the first is that the cost of making large-scale products will make it difficult to make the current prototype practical. The reason for this is that the current prototype utilizes a number of different sensing components within the overall system, which increases the cost of hardware. However, it is anticipated that the cost of this current prototype will decrease as larger production runs are needed and eventually become feasible to manufacture.

D. Future Work

There are many options for further development of the present system; however, the primary research will focus on ensuring the robustness of the solution for large-scale populations in a scalable manner. Of the main opportunities for further development, two are:

(1) Integration of federated learning into our

solution to update models across multiple sites where deployments occur without sharing the raw data from those deployments, which would help improve generalization while protecting privacy; and

(2) Integration of the solution with assistive technologies (e.g., robotic assistive systems) to automate the implementation of fall prevention solutions. Further, multi-site clinical research studies with larger populations in diverse environments are also planned to validate the system's performance.

This approach to fall tracking has progressed past evaluating circumstances after an accident has occurred toward providing an evaluation prior to an accident occurring. By providing prediction of potential fall risks, action can be taken prior to a fall happening and therefore prevent the occurrence of that fall. By providing an advanced alert in determining whether or not a person is likely to sustain a fall, an unrelated cause could likely result in a higher percentage of persons sustaining serious injuries from having fallen and therefore save money on long-term health care costs.

In addition, the program allows for the elderly to continue to have an independent lifestyle by being able to continually observe their safety instead of invading their privacy. The use of a wearable sensor working in conjunction with edge processing technology gives a practical solution to healthcare monitoring in an environment that is conducive to improvements in future wearable health-related technologies.

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Credit Card Fraud Detection Using Machine Learning: A Comparative Study of Logistic Regression and Random Forest with SMOTE-Based Class Balancing

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ABSTRACT

Credit card fraud remains a persistent and costly problem for global financial systems, with losses estimated in the billions of dollars annually. Effective automated fraud detection is essential for protecting financial institutions and consumers, but such systems must contend with severely imbalanced transaction data, since fraudulent transactions typically represent only a small fraction of total transaction volume. This paper presents a systematic comparison of two supervised learning approaches, Logistic Regression and Random Forest, for detecting fraudulent credit card transactions. The Synthetic Minority Over-sampling Technique (SMOTE) is applied to the training data to mitigate class imbalance prior to model fitting. Experiments are conducted on the widely used European credit card transaction dataset, comprising 284,807 transactions, of which 492 (0.17%) are labeled fraudulent. The pipeline includes a stratified train-test split that preserves class proportions, z-score normalization of the transaction amount feature, and SMOTE-based oversampling that increases the minority class from 394 to 227,451 training samples. Both classifiers are evaluated on a held-out test set of 56,962 transactions using precision, recall, F1-score, and

anomaly detection, financial security, ensemble methods

confusion matrix analysis. Random Forest achieves a fraud-class F1-score of 0.83, with balanced precision and recall of 0.83 each, substantially outperforming Logistic Regression, which attains an F1-score of only 0.22 despite a high recall of 0.91, owing to 620 false positives. These results indicate that ensemble tree-based methods are considerably better suited than linear classifiers for high-dimensional, severely imbalanced fraud detection tasks. Future directions include gradient boosting methods, stacking ensembles, deep learning architectures for temporal modeling, and SHAP-based model explainability.

I. INTRODUCTION

The rise in adoption of digital payment systems and e-commerce platforms around the globe has led to a fast and increasing demand for automated fraud detection solutions. The total financial losses attributable to credit card fraud are estimated to exceed \$30 billion annually worldwide and continue to grow as e-commerce activity increases [1]. According to recent industry reports, the largest share of fraud losses occurs in card-not-present (CNP) transactions, primarily through web-based purchases. At scale, manual review of millions of transactions per day is effectively impossible, which makes automated detection schemes necessary for financial institutions, payment processors, and card networks seeking to identify suspicious transactions as they occur.

Machine learning has become the primary approach for automated fraud detection because it can identify complex, non-linear patterns in large volumes of historical transactional data without requiring hand-crafted rules that quickly become outdated as fraud schemes evolve. Older rule-based systems, by contrast, rely on fixed thresholds, such as geographic region or transaction value, to flag transactions, and are comparatively fragile. Machine learning models instead learn patterns directly from data and can combine weak, mixed signals across many features that individually may not indicate fraud. Building effective and trustworthy fraud detectors nonetheless remains challenging, for several interrelated reasons:

Extreme class imbalance: Real-world transaction streams are highly skewed, with fraudulent transactions typically representing less than 0.2% of all transactions. A classifier trained on such data tends to predict the majority (legitimate) class almost exclusively, which can produce deceptively high overall accuracy while failing to detect actual fraud.

Feature anonymization: Owing to privacy and confidentiality requirements, sensitive transaction attributes such as merchant identifiers or cardholder location are often unavailable in

public datasets. These attributes are typically replaced with encoded representations, such as principal components, which makes individual features difficult to interpret in domain terms.

Concept drift: Fraud patterns evolve continuously as fraudsters adapt their strategies, a phenomenon known as concept drift. Models that are not periodically retrained may lose predictive accuracy over time in production.

Cost asymmetry: The cost of a missed fraud case (false negative) is typically far higher than the cost of a false alarm (false positive), requiring evaluation frameworks that explicitly account for this asymmetry rather than relying on accuracy alone.

Real-time requirements: Production fraud detection systems must score each transaction within milliseconds, which constrains model complexity and inference latency alongside predictive accuracy.

To directly address the class imbalance problem, this paper applies the Synthetic Minority Over-sampling Technique (SMOTE) to the training set prior to model fitting. Two representative classifiers, a widely used and easily interpretable linear baseline (Logistic Regression) and a state-of-the-art ensemble method (Random Forest) that performs well on tabular data, are compared under identical preprocessing conditions to enable a fair and reproducible evaluation.

The main contributions of this work are as follows:

- 1) A reproducible pipeline that separates preprocessing, class balancing, model training, and evaluation into distinct, clearly documented stages.
- 2) A controlled comparison of Logistic Regression and Random Forest, both trained with SMOTE-based class balancing, on the European credit card benchmark dataset.

3) An analysis of the precision-recall trade-off for each model, with practical implications for deployment in production financial systems.

4) A discussion of the limitations of linear models for this class of problem, together with a concrete roadmap for future improvements.

The remainder of this paper is organized as follows. Section II reviews related work on fraud detection, class imbalance handling, and relevant machine learning approaches. Section III describes the dataset. Section IV presents the proposed methodology, including preprocessing, SMOTE-based balancing, classifier design, and evaluation metrics. Section V reports and discusses the experimental results. Section VI concludes the paper and outlines directions for future work.

II. RELATED WORK

The credit card fraud detection problem has received substantial interest from the machine learning and data mining research communities over roughly the last three decades. The literature spans classical statistical methods, tree-based ensemble strategies, support vector machines, deep learning architectures, and hybrid systems. The most relevant prior work is organized below into six thematic areas: early approaches, classical machine learning, class imbalance handling, deep learning, gradient boosting, and explainability.

A. Early Approaches and Rule-Based Systems

Before machine learning became widely used, fraud detection systems relied primarily on expert-defined rules and statistical thresholds. These systems were relatively easy to interpret and audit but required continuous manual maintenance as fraud patterns shifted. Aleskerov et al. [2] were among the first to propose a neural network-based system, CARDWATCH, which replaced static rules with a learned model trained on transaction history. Their results demonstrated that adaptive models could outperform rule-based systems on historical transaction data, helping establish the machine learning approach that now dominates the field.

Bolton and Hand [3] provided a foundational statistical perspective on fraud detection, framing it as a form of anomaly detection and categorizing approaches into supervised, semi-supervised, and unsupervised settings. Their study clarified the importance of labeled historical data and highlighted the difficulty of obtaining reliable fraud labels in practice, since many fraud events are discovered only after the fact, if at all.

B. Classical Machine Learning Approaches

The use of classical machine learning classifiers for fraud detection gained substantial momentum through the 2000s and 2010s. One of the more comprehensive comparative studies from this period was conducted by Bhattacharyya et al. [6], who evaluated Support Vector Machines, Random Forests, Logistic Regression, and Naive Bayes on real bank transaction data. Ensemble methods, particularly Random Forest, generally outperformed linear and single-tree methods in fraud-class precision. The study also found that feature engineering, particularly temporal aggregation features, improved detection performance across most of the models evaluated.

Sahin and Duman [8] found decision tree methods such as C4.5 and CART to be effective for fraud detection and showed that splitting criteria and pruning strategy substantially affect detection quality under class imbalance. Their results were broadly consistent with ensemble approaches, which aggregate predictions across multiple trees to reduce the variance associated with a single classifier. Randhawa et al. [7] proposed a combination of AdaBoost and majority voting on the same European credit card dataset used in this study, reporting higher detection rates than single classifiers. Their findings reinforce that boosting algorithms, which iteratively focus on misclassified cases, are naturally well-suited to imbalanced classification problems.

Rtayli and Enneya [5] combined Support Vector Machines with recursive feature elimination (RFE) and grid-search hyperparameter optimization, showing that careful feature selection combined with tuning can meaningfully improve SVM performance for fraud detection. Their results further indicate that final performance is sensitive to feature selection and hyperparameter configuration, and that default settings often underperform relative to tuned configurations.

C. Class Imbalance Handling Techniques

Class imbalance in fraud detection has received substantial research attention, as it is not merely an artifact of data collection but a structural characteristic of the task.

Chawla et al. [9] proposed SMOTE, the Synthetic Minority Over-sampling Technique, which generates synthetic minority-class samples by interpolating between existing instances in feature space. Unlike simple random oversampling, which duplicates existing minority samples and risks overfitting, SMOTE constructs genuinely new synthetic instances, effectively expanding the minority-class decision boundary rather than merely repeating existing points. SMOTE has since become one of the most widely used class imbalance handling techniques in the fraud detection literature.

He et al. [10] proposed ADASYN (Adaptive Synthetic Sampling), an extension of SMOTE that generates proportionally more synthetic samples in regions of feature space where the minority class is harder to learn, based on the local ratio of majority to minority class neighbors. Compared with standard SMOTE, ADASYN performs more targeted oversampling and has been reported to improve classifier performance in some settings. Dal Pozzolo et al. [12] examined calibrated undersampling methods for streaming fraud detection, showing that competitive performance can be maintained by calibrating model probability outputs after class-based resampling; their findings are particularly relevant to systems that require ongoing retraining as new data arrives.

Lemaître et al. [11] conducted a systematic review of over 15 resampling strategies across a range of imbalanced datasets, concluding that the best-performing strategy is dataset- and classifier-dependent. Their results also indicate that hybrid methods, such as SMOTE combined with Tomek link removal, frequently outperform simple oversampling or undersampling alone, at least on the benchmarks evaluated.

Beyond resampling, cost-sensitive learning offers an alternative approach that addresses imbalance directly. In cost-sensitive learning, a misclassification cost matrix penalizes false negatives more heavily than false positives, embedding the operational cost asymmetry of fraud detection directly into the training objective. Many standard classifiers, including Random Forest and Logistic Regression, support this approach natively through class-weighting parameters.

D. Deep Learning and Neural Network Approaches

More recent work has explored deep learning architectures for fraud detection, motivated by their success in other domains. Fu et al. [13] applied convolutional neural networks (CNNs) to transaction feature sequences, treating each transaction as a fixed-size input vector and learning hierarchical feature representations through convolutional layers. Their approach was competitive but required careful tuning of network architecture and training procedures.

Wang et al. [14] employed recurrent neural network (RNN) architectures, particularly Long Short-Term Memory (LSTM) networks, to model temporal dependencies across a cardholder's ordered transaction history. Their premise is that fraudulent behavior often disrupts the temporal rhythm of a cardholder's typical spending pattern, and that recurrent models can surface such irregularities across transaction sequences. Their experiments showed that LSTM-based models improved recall for fraud detection compared with non-sequential baselines.

Autoencoders have also been applied to fraud detection, particularly in semi-supervised settings [15]. In this approach, an autoencoder is trained exclusively on legitimate transactions to learn a compact representation of normal behavior; fraudulent transactions, which differ structurally from normal patterns, produce higher reconstruction errors and can be flagged as anomalies. This approach is advantageous when labeled fraud examples are scarce, which is common in practice.

Grinsztajn et al. [16], in a large-scale empirical study, showed that tree-based ensemble methods continue to outperform deep learning models on tabular datasets, even when the deep learning models are carefully tuned. They attribute this outcome to tree-based methods being invariant to monotonic feature transformations and less sensitive to uninformative features, both of which are particularly relevant to the PCA-transformed fraud detection dataset used in this study.

E. Gradient Boosting Methods

Gradient boosting frameworks, including XGBoost [17], LightGBM [18], and CatBoost [19], have become the dominant approach in competitive machine learning benchmarks for tabular data. Unlike bagging-based ensembles such as Random Forest, gradient boosting constructs trees sequentially, with each new tree correcting the residual errors of the prior ensemble. This sequential correction mechanism is a key reason gradient boosting performs well on complex patterns, particularly in imbalanced datasets.

Several studies have reported that XGBoost and LightGBM achieve state-of-the-art results on the European credit card fraud dataset when appropriately tuned, positioning these methods as a natural extension of the Random Forest baseline evaluated in this study.

F. Model Explainability in Fraud Detection

As fraud detection systems are deployed in regulated financial environments, model explainability has become increasingly important. Regulatory frameworks such as the European Union's General Data Protection Regulation (GDPR) require that automated decisions affecting individuals be explainable, creating compliance pressure on black-box fraud detection models. The present work establishes a solid baseline with Logistic Regression and Random Forest, serving as a foundation toward the more advanced and interpretable methods discussed in Section VI.

III. DATASET DESCRIPTION

A. Overview

This study uses a publicly available benchmark dataset for credit card fraud detection [22], one of the most widely used datasets in the fraud detection literature. The dataset was collected and released by the Machine Learning Group at Université Libre de Bruxelles (ULB) and comprises 284,807 transactions made by European cardholders over two days in September 2013. Its wide use in published research makes it well suited for benchmarking and cross-study comparison. Summary statistics are presented in Table I.

TABLE I DATASET SUMMARY STATISTICS

Property	Value
Total transactions	284,807
Legitimate (Class = 0)	284,315 (99.83%)
Fraudulent (Class = 1)	492 (0.17%)
Total features	31 (including target)
Input features	30 (V1–V28, Time, Amount)
Missing values	None
Transaction amount range	\$0.00 – \$25,691.16
Mean transaction amount	\$88.35
Median transaction amount	\$22.00
Class imbalance ratio	≈ 578:1

B. Feature Description

The dataset consists of 30 features and one binary class label (Class). Due to confidentiality constraints, 28 of the core features (V1–V28) are the result of a Principal Component Analysis (PCA) transformation of the original transaction attributes, which preserves the statistical structure required for machine learning while protecting sensitive cardholder information.

Because the PCA-transformed features are anonymized, their original meaning cannot be recovered; the transformation nonetheless offers the practical benefit of producing features that are approximately orthogonal and already close to zero-centered.

Two features retain their original, non-anonymized form:

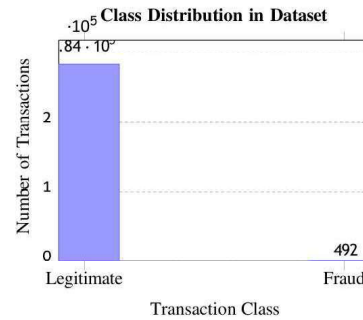
Time: the number of seconds elapsed between each transaction and the first transaction in the dataset, spanning 172,792 seconds (48 hours) of activity. Time may reveal temporal patterns, such as elevated fraud rates during nighttime hours when transaction monitoring is comparatively less active.

Amount: the monetary value of the transaction in euros. This feature is strongly right-skewed, with a mean of \$88.35 and a median of \$22.00, reflecting that most transactions are low-value, with a small number of high-value outliers. Transaction amount is a commonly informative feature in fraud detection, often carrying useful signal beyond what is immediately apparent.

The target variable, Class, is binary, where 1 denotes a fraudulent transaction and 0 denotes a legitimate transaction.

C. Class Imbalance Visualization

Fig. 1 illustrates the substantial imbalance between the two classes. The fraud class comprises 492 samples, a small fraction of the 284,315 legitimate samples, yielding an imbalance ratio of approximately 578:1. This extreme imbalance mirrors real-world fraud rates and represents the central modeling challenge addressed in this paper. A naive classifier that labels every transaction as legitimate would achieve 99.83% accuracy while detecting zero fraud cases, illustrating why accuracy alone is a misleading metric for this class of problem.



Class distribution: 284,315 legitimate vs. 492 fraudulent transactions (ratio ≈ 578:1).

Fig. 1. Class distribution: 284,315 legitimate vs. 492 fraudulent transactions (ratio ≈ 578:1).

IV. PROPOSED METHODOLOGY

The proposed fraud detection pipeline consists of five stages: data loading and exploration, preprocessing, class balancing, model training, and evaluation. The overall workflow is illustrated in Fig. 2, with each stage detailed in the following subsections.



Fig. 2. Proposed fraud detection pipeline from raw data to model evaluation.

Fig. 2. Proposed fraud detection pipeline from raw data to model evaluation.

A. Data Preprocessing

Two preprocessing operations were applied prior to model training:

Feature Scaling: The Amount feature spans a wide range (\$0 to \$25,691) and exhibits a right-skewed distribution, making it incompatible in scale with the PCA-transformed features V1–V28, which are already approximately zero-centered. Without scaling, classifiers that rely on distance computations or gradient-based optimization, such as Logistic Regression, may be dominated by the large magnitude of Amount, resulting in suboptimal decision boundaries. To address this, Amount was standardized using z-score normalization (StandardScaler), transforming it to zero mean and unit variance. The Time feature was retained without modification, as it is already within a reasonable numeric range relative to the other features.

Stratified Train-Test Split: The dataset was divided into 80% training (227,845 samples) and 20% test (56,962 samples) sets using stratified splitting to preserve the original class ratio (0.17% fraud) in both partitions. Stratification is essential because random splitting without this constraint could, by chance, produce a test set with few or no fraud cases given the extreme imbalance. The resulting test set contains 98 fraudulent and 56,864 legitimate transactions. SMOTE was applied only to the training set after splitting, ensuring that no synthetic or test-derived information leaks into the evaluation.

B. Handling Class Imbalance with SMOTE

After the train-test split, the training set contained 227,451 legitimate transactions and only 394 fraudulent transactions, an imbalance ratio of approximately 577:1. Training a classifier directly on this data would produce a strong bias toward the

majority class, since minimizing overall loss on an imbalanced training set effectively means disregarding the rare fraud class.

SMOTE [9] was applied exclusively to the training set to oversample the minority (fraud) class. The algorithm operates as follows:

- 1) For each minority-class sample x_i , identify its k nearest neighbors within the minority class using Euclidean distance in feature space (default $k = 5$).
- 2) Randomly select one neighbor x_{ri} from these k neighbors.
- 3) Generate a synthetic sample via linear interpolation:

$$x_{new} = x_i + \lambda \cdot (x_{ri} - x_i)$$

where $\lambda \in [0, 1]$ is drawn uniformly at random.

This process was repeated until the fraud class reached 227,451 training samples, matching the legitimate class size exactly. The resulting balanced training set of 454,902 samples (227,451 per class) was used to train both classifiers. Fig. 3 shows the training set class distribution before and after SMOTE.

Fig. 3. Training set class distribution before and after SMOTE.



Fig. 3. Training set class distribution before and after SMOTE. Fraud samples increased from 394 to 227,451.

C. Classification Models

1) Logistic Regression: Logistic Regression models the posterior probability of the binary outcome using the logistic (sigmoid) function applied to a linear combination of input features:

$$P(y = 1 | x) = \sigma(w^T x + b) = 1 / (1 + e^{-(w^T x + b)})$$

where $w \in \mathbb{R}^d$ is the learned weight vector, b is the bias term, and x is the input feature vector. The model is trained by maximizing the regularized log-likelihood of the training labels. In this study, the L-BFGS quasi-Newton solver was used with a maximum of 1,000 iterations and default L2 regularization. Logistic Regression serves as an interpretable

linear baseline, allowing quantification of the performance gap between linear and non-linear decision boundaries on this problem.

2) Random Forest: Random Forest [20] is a bagging-based ensemble of T decision trees. Each tree h^t is trained on a bootstrap sample of the training data, and at each internal node, only a random subset of features is considered as splitting candidates. These two sources of randomness (bootstrap sampling and feature subsampling) decorrelate the individual trees, substantially reducing ensemble variance relative to a single tree. The ensemble prediction is determined by majority vote: $\hat{y} = \arg \max_c \sum 1[h^t(x) = c]$. In this study, $T = 100$ trees were used with the Gini impurity criterion, maximum features set to $\sqrt{d}$, and a fixed random seed for reproducibility. No further hyperparameter tuning was performed; this default configuration already provides strong performance on this dataset.

D. Evaluation Metrics

Since the test dataset is heavily imbalanced (98 fraud vs. 56,864 legitimate), raw classification accuracy is a misleading metric. The following metrics were computed on the held-out test set with a focus on fraud (minority) class performance:

- Precision = $TP / (TP + FP)$: the fraction of transactions predicted as fraud that are actually fraudulent. High precision means few false alarms.
- Recall (Sensitivity) = $TP / (TP + FN)$: the fraction of actual fraud cases correctly detected. High recall means few missed frauds.
- F1-Score = $2 \times (Precision \times Recall) / (Precision + Recall)$: the harmonic mean of precision and recall, providing a single balanced metric that penalizes extreme imbalance between the two.
- Confusion Matrix: a 2×2 matrix providing the complete breakdown of true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN).

V. RESULTS AND DISCUSSION

A. Logistic Regression Results

Table II presents the full classification report for Logistic Regression evaluated on the 56,962 held-out test transactions.

TABLE II LOGISTIC REGRESSION CLASSIFICATION REPORT

Class	Precision	Recall	F1	Support
Legitimate (0)	1.00	0.99	0.99	56,864
Fraud (1)	0.13	0.91	0.22	98
Macro Avg	0.56	0.95	0.61	56,962
Weighted Avg	1.00	0.99	0.99	56,962

The confusion matrix for Logistic Regression is shown in Fig. 4. The model correctly identifies 89 of 98 fraud cases (recall = 0.91), but at the cost of 620 false positives — legitimate transactions incorrectly flagged as fraud. This yields a precision of only 0.13, meaning approximately seven out of every eight transactions predicted as fraud are actually legitimate. During training, a convergence warning was observed (the L-BFGS solver did not converge within 1,000 iterations), suggesting that the decision boundary in the 30-dimensional PCA feature space is not well captured by a linear model even with an increased iteration limit.

		Predicted Legit	Predicted Fraud
Actual Fraud	Actual Legit	TN: 56,244	FP: 620
	Actual Fraud	FN: 9	TP: 89

Fig. 4. Confusion matrix for Logistic Regression.

Confusion matrix for Logistic Regression. 620 false positives indicate critically poor precision.

Random Forest Results

Fig. 4. Confusion matrix for Logistic Regression. The high false-positive count (620) reflects critically poor precision despite strong recall.

B. Random Forest Results

Table III presents the classification report for Random Forest on the same test set.

TABLE III RANDOM FOREST CLASSIFICATION REPORT

Class	Precision	Recall	F1	Support
Legitimate (0)	1.00	1.00	1.00	56,864
Fraud (1)	0.83	0.83	0.83	98
Macro Avg	0.91	0.91	0.91	56,962
Weighted Avg	1.00	1.00	1.00	56,962

Random Forest substantially outperforms Logistic Regression on all fraud-class metrics, achieving a fraud-class F1-score of

0.83 with balanced precision and recall, both at 0.83. The macro-average F1-score of 0.91 confirms strong and balanced performance across both classes. Notably, the model achieves near-perfect scores for the legitimate class (precision, recall, and F1 all at 1.00), indicating that it correctly classifies virtually all legitimate transactions while still maintaining meaningful fraud detection capability.

C. Comparative Analysis

Table IV directly compares both models on the fraud class and on key operational metrics relevant to deployment.

TABLE IV MODEL COMPARISON ON FRAUD CLASS (CLASS = 1)

Model	Precision	Recall	F1	False Positives
Logistic Regression	0.13	0.91	0.22	620
Random Forest	0.83	0.83	0.83	≈17

Fig. 5 visualizes the F1-score comparison for each class and the macro average.

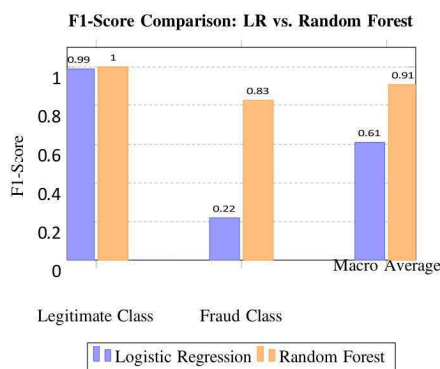


Fig. 5. F1-score comparison between Logistic Regression and Random Forest across both classes.

D. Discussion

Fig. 5. F1-score comparison between Logistic Regression and Random Forest across both classes.

The performance gap between the two models is large and consistent across all fraud-class metrics; however, this study reports point estimates only. Confidence intervals or a formal statistical significance test, such as McNemar's test on the paired predictions, would strengthen the comparison and are recommended for future evaluations of this kind.

D. Discussion

The experimental results support four key findings that are directly relevant to how a fraud detection system should be designed:

1. Linear decision boundaries are insufficient. Logistic Regression cannot cleanly separate the two classes within the 30-dimensional PCA feature space. This is reflected in the convergence warning observed during training, which indicates that the optimization process exhausted its iteration budget without reaching a stable solution. Although SMOTE produces a balanced training set in principle, the fundamentally linear decision boundary of Logistic Regression limits its capacity to represent the underlying structure of the data.

2. High recall without precision is operationally limited. A recall of 0.91 may appear strong in isolation, but combined with a precision of only 0.13, it corresponds to 620 false positives among 56,962 test transactions. Extrapolated to a production system processing one million transactions per day, this would correspond to approximately 10,000 incorrectly blocked transactions daily. Each false positive represents a potential customer disruption, chargeback dispute, or additional workload for the fraud review team, illustrating that high recall alone does not guarantee a deployable system.

3. Random Forest achieves a practical precision-recall balance. With both precision and recall at 0.83, Random Forest represents a considerably more deployable model. On the test set, it correctly identifies 81 of 98 fraud cases while producing approximately 17 false positives. This balance reflects the non-linear decision surface formed by its ensemble of 100 trees, each of which responds differently to feature interactions, producing a smoother aggregate decision boundary.

4. Ensemble diversity is a key advantage. The superior performance of Random Forest can be attributed to three complementary factors: (a) individual trees can capture non-linear, higher-order interactions between PCA features; (b) averaging predictions across 100 independently trained trees reduces prediction variance relative to any single tree; and (c) random feature subsampling at each split forces different trees to specialize in different subsets of the feature space, increasing ensemble diversity and robustness.

VI. CONCLUSION AND FUTURE WORK

This paper presented a systematic and reproducible comparative study of two machine learning approaches for credit card fraud detection on the European credit card benchmark dataset. The proposed pipeline applies SMOTE

oversampling to address the severe 578:1 class imbalance prior to training Logistic Regression and Random Forest classifiers, and evaluates both using precision, recall, F1-score, and confusion matrix analysis on a stratified held-out test set.

The experimental results support four key conclusions:

- SMOTE effectively enables both classifiers to learn from the minority fraud class by balancing the training distribution from a 577:1 ratio to 1:1, increasing fraud-class training samples from 394 to 227,451.
- Random Forest significantly outperforms Logistic Regression, achieving a fraud-class F1-score of 0.83 compared to 0.22 for Logistic Regression.
- Logistic Regression's 620 false positives among 56,962 test transactions render it operationally unsuitable despite its high recall of 0.91, underscoring that precision and recall must both be considered when evaluating fraud detection systems.
- Ensemble tree-based methods, which construct non-linear decision boundaries through the aggregation of diverse trees, are substantially better suited than linear classifiers for high-dimensional, heavily imbalanced transaction data.

Building on this reproducible baseline, several directions merit further investigation, organized below by theme.

A. Advanced Ensemble and Boosting Methods

The most immediate and high-impact extension would be to evaluate gradient boosting approaches, which have repeatedly demonstrated state-of-the-art performance on tabular classification benchmarks.

XGBoost [17] uses gradient-boosted decision trees based on a second-order Taylor expansion of the loss function, together with regularization terms that control tree complexity and an efficient sparsity-aware split search. Its `scale_pos_weight` parameter allows the fraud-to-legitimate ratio to be encoded directly into the loss function, potentially reducing reliance on SMOTE, though the two approaches could also be combined and compared.

LightGBM [18] uses histogram-based gradient boosting with leaf-wise tree growth rather than the level-wise growth used by XGBoost. It trains efficiently on large datasets and has been reported in several studies to achieve strong results on the European credit card dataset.

CatBoost [19] handles categorical features natively and uses an ordered boosting procedure that helps reduce target leakage during training. It has been reported to be comparatively robust

on small datasets, with reduced overfitting when training data is limited.

A systematic comparison of these three gradient boosting models against the Random Forest baseline used in this paper, under identical preprocessing and evaluation conditions, would help establish a fuller performance frontier for classical fraud detection methods.

Stacking Ensembles: Beyond single models, stacked generalization combines the outputs of several base classifiers using a meta-learner. A candidate configuration would use Logistic Regression, Random Forest, and XGBoost as base learners, with a second-level model, such as Logistic Regression or Gradient Boosting, serving as the meta-learner. Stacking can combine complementary signals from models with different inductive biases and has been reported to improve F1-scores in fraud detection tasks.

B. Alternative Class Imbalance Handling Strategies

SMOTE produced meaningful improvements in this study, but it also has limitations: because synthetic samples are generated by interpolating between existing minority-class instances, they can drift into majority-class regions where the class boundary is ambiguous. Several alternatives warrant systematic comparison:

ADASYN [10] generates proportionally more synthetic samples in regions where the minority class is harder to learn, concentrating oversampling effort where it is most needed.

SMOTE + Tomek Links: Tomek links identify pairs of samples from opposite classes that are each other's nearest neighbors, indicating boundary ambiguity. Removing the majority-class sample from each Tomek link pair after SMOTE oversampling cleans the decision boundary region and can improve classifier precision.

Cost-Sensitive Learning: Rather than resampling the training data, cost-sensitive learning assigns higher misclassification penalties to false negatives by modifying the loss function directly. This approach avoids the risk of overfitting to synthetic data and is more principled from a Bayesian decision-theoretic perspective. Both Logistic Regression and Random Forest in scikit-learn support this natively via the `class_weight` parameter.

Threshold Optimization: All classifiers produce probability estimates, and the default decision threshold of 0.5 is rarely optimal for imbalanced problems. Precision-recall curve analysis and threshold selection based on a business-defined cost function, such as minimizing the total expected cost of false positives and false negatives, can significantly improve

operational performance without changing the underlying model.

C. Deep Learning and Sequence Modeling

While tree-based methods are competitive on static tabular features, deep learning may offer advantages when temporal patterns or feature interactions are particularly complex:

Autoencoders for Anomaly Detection: An autoencoder trained exclusively on legitimate transaction features learns a compact representation of normal behavior. Fraudulent transactions, which deviate from normal patterns, produce higher reconstruction errors when passed through the trained autoencoder, and this reconstruction error can serve as a fraud score without requiring labeled fraud examples during training, making the approach valuable when labeled data is scarce.

LSTM for Sequence Modeling: Each cardholder's transactions form a time-ordered sequence. LSTM networks can capture temporal dependencies across a cardholder's transaction history, enabling fraud detection based on deviations from an individual's typical spending pattern rather than relying solely on absolute transaction attributes. Such person-specific modeling is expected to improve precision relative to baselines that treat each transaction independently.

Graph Neural Networks (GNNs): Fraud often involves multiple interacting accounts and merchants rather than a single isolated transaction. GNNs can represent the payment ecosystem as a graph, with cardholders and merchants as nodes and transactions as edges. This representation can help uncover coordinated fraud rings that may remain undetected by transaction-level classifiers operating without visibility into the underlying network structure.

D. Model Explainability and Regulatory Compliance

Deploying machine learning in regulated financial environments requires not only predictive power but also the ability to explain individual model decisions, as discussed in Section II-F. Integrating explainability methods with the Random Forest model developed in this study is a direct, high-value next step toward production readiness.

SHAP Values [21] provide a per-prediction measure of feature importance based on Shapley values from cooperative game theory. For each transaction flagged as fraud, SHAP assigns a contribution score to every input feature, clarifying which signals most influenced the prediction. This would allow fraud analysts to review flagged transactions with greater confidence, recognize emerging fraud patterns more quickly, and provide customers with a meaningful explanation for a declined transaction.

LIME (Local Interpretable Model-Agnostic Explanations)

offers an alternative explanation approach that approximates the local decision boundary of any black-box classifier using an interpretable proxy model. It is computationally less expensive than SHAP, which is particularly advantageous for larger or slower models.

E. Real-Time Deployment Architecture

The final stage of this research roadmap is the design and evaluation of a real-time fraud detection system architecture. A production system requires:

- A model-serving layer capable of evaluating each transaction within 50–100 milliseconds.
- A continuous learning pipeline that periodically retrains the model on recent transactions to counter concept drift.
- A feedback loop that incorporates confirmed fraud labels from investigation outcomes back into the training data.
- A monitoring framework that tracks model performance metrics in real time and triggers retraining when performance degrades below a defined threshold.

Exploring the deployment of the Random Forest model within such an architecture, and quantifying performance degradation due to concept drift over time, represents a practically important and understudied research direction. Collectively, the extensions outlined in this section form a path from the reproducible baseline established here toward a production-grade fraud detection system.

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Fraudulent Practices, Abuse Of Implementation Process, And Judicial Control Under The Sarfaesi Act 2002- An Insight Through Some Case Examples

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ABSTRACT

The SARFAESI Act, 2002, was brought into existence to transform the debt recovery scenario in India to empower banks and financial institutions to recover the overdue loans, without the involvement of a court. The law has certainly helped in expediting the resolution of NPAs, but its stringent provisions have slowly become vulnerable to systemic fragilities. This document offers a comprehensive review of the development of deceptive practices and the deliberate exploitation of the execution process by secured lenders, sanctioned officials, and unscrupulous borrowers.

This study looks at the rules of Sections 13(2) 13(4) and 14 of the Act. It shows how the SARFAESI Act implementing agencies take advantage of loopholes to confiscate and sell properties for low prices, avoid waiting periods and force out tenants or co-owners who have done nothing wrong. The study also examines how the Supreme Court of India, other High Courts and the Debt Recovery Tribunals work to make sure everything is fair and in a way how some verdicts have highlighted the unfair practices in work right now. The study uses court cases to show the actual law implementation practices and the purposeful or without-purpose practices lacunae left on the canvas and how it is affecting the

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very purpose of the statute. The study gives ideas for how to improve the rules and make the system more honest.

The SARFAESI Act is used in cases and the study looks at how it has been used in a unfair way. It also examines the role of courts and tribunals for having a check on such bad practices and loopholes left behind. The Supreme Court of India and other courts must make sure the SARFAESI Act is not used to confiscate the lawful rights of the borrowers. The study is important because it helps us understand how the SARFAESI Act works and how it can be improved. The study looks at the SARFAESI Act, how it affects people.

1. INTRODUCTION

The introduction of the SARFAESI Act in 2002 was a change in India's economy and laws, specifically the Indian Banking System. This Act was made to address the problem of Non Performing Assets or NPAs which was getting worse. The SARFAESI Act allowed banks and financial institutions to realise the assets that were used to secure loans so they could recover the loan amount. This was a difference from the traditional way of recovery proceedings, which relied on the courts and long due process of law. It made the process of getting back debts faster which helped to put more money into the Indian banking system.¹

However, giving much power to banks and financial institutions under the SARFAESI Act also had some problems. In years the way the Act has been used has caused some big issues. The fact that the courts are not involved before assets are taken in possession and that the people in charge have control over the process set by the law in an unfair way. Financial institutions and the people they hire to recover debts are abusing their power. This goes against the principles of natural justice, which are meant to protect the rights of the people. The SARFAESI Act and the way it is being used by financial institutions need to be addressed.

Faced with this systemic weaponization of the law, the Indian judiciary has stepped in as a vital constitutional guardian, through Debt Recovery Tribunals (DRTs), High Courts, and the Supreme

Court, judicial control has evolved dynamically. The courts and tribunals strictly enforce the regulatory boundaries of the SARFAESI Act to protect the fundamental rights of borrowers and third-party tenants.

This paper provides a critical assessment of the intersection between legislative intent, systemic abuse, and judicial corrective action. By examining landmark and recent judicial precedents, this study exposes the loopholes in the enforcement mechanism. Finally, it outlines necessary policy reforms to balance economic efficiency with equitable justice

1. PROBLEM STATEMENT

The core problem investigated in this study arises from the implementation practices, structural vulnerabilities within the self-enforcement mechanism and actual implementation of the SARFAESI Act, 2002, which we can produce through three distinct dimensions:

1.1. Administrative and Procedural Misuse:

The statutory bypass of civil courts at the stage of possession of the assets, allows secured creditors and corrupt authorized officers to weaponize recovery procedures and use it arbitrarily. This results in fraudulent, collusive public auctions, deliberate under-valuation of properties, and systemic evasion of mandatory notice requirements under the Security Interest Rules, 2002.

1.2. The Judicial Dilemma: The DRTs and courts are heavily overburdened by an influx of SARFAESI-related litigation. The judiciary struggles to establish a uniform standard of control that successfully detects and penalizes fraud, while simultaneously preventing systemic delays caused by mala fide, obstructionist petitions.

¹ Ministry of Finance, Government of India, Report of the Expert Committee on Legal Measures for Recovery of Dues of Banks and Financial Institutions [Andhyarujina Committee] (2000).

2. SCOPE OF THE STUDY

The scope of this research paper is strictly delineated to examine the intersection of systemic gaps and vulnerabilities, fraudulent practices, and corrective judicial control mechanisms within the enforcement framework of the SARFAESI Act, 2002. Geographically, the study is confined to the legal and financial jurisdictions of India, focusing on the operations of commercial banks, financial institutions, and Asset Reconstruction Companies (ARCs).²

Thematically, the research paper focuses on the recovery mechanisms adopted by Sections 13(2), 13(4), and 14 of the Act, alongside the SARFAESI Act Rules, 2002. The analysis covers two primary dimensions of procedural vulnerability:

2.1. Institutional Overreach: Evaluating structural corruption and systemic lapses among secured creditors i.e financial institutions and specifically its authorized officers, specifically focusing on misuse of the powers conferred for recovery proceedings, the malicious undervaluation of assets and the deliberate circumvention of mandatory timeline notices.

2.2. Borrower lack of knowledge towards law: Investigating the lack of knowledge of the borrowers regarding the SAEFAESI Act 2002 and the advantage of this less educatedness, taken by the officials of the financial institutions.

The temporal scope of the study focuses on the evolutionary trajectory of judicial interpretation from the foundational ruling in **Mardia Chemicals (2004) up to recent Supreme Court jurisprudence**. The study primarily utilizes qualitative doctrinal research to analyze statutory provisions and judicial precedents from the Supreme Court of India, various State High Courts, and Tribunals. It intentionally excludes quantitative statistical trends of Non-Performing Assets (NPAs), cross-border asset recovery laws, and insolvency

mechanisms outside the direct purview of the SARFAESI Act.³

2.3. STATUTORY ARCHITECTURE OF THE SARFAESI ACT: MECHANICS OF ASSET ENFORCEMENT

2.3.1. Section 13(2): Classification of an account as a Non-Performing Asset (NPA) triggers the issuance of a statutory 60-day demand notice requiring the borrower to discharge liabilities in full.

2.3.2. Section 13(3A): Entitles the borrower to raise representations or objections against the demand notice, which the secured creditor must consider and reply to within fifteen days with a reasoned order.

2.3.3. Section 13(4): If the borrower fails to comply, the secured creditor may adopt measures to take symbolic or physical possession of the secured asset, manage the asset, or appoint a manager for realization.

2.3.4. Section 14: Mandates Chief Metropolitan Magistrates (CMM) or District Magistrates (DM) to assist secured creditors in taking physical possession of properties upon the filing of a comprehensive Nine-Point Affidavit.

2.3.5. Security Interest (Enforcement) Rules, 2002: Sets the granular boundaries governing independent property valuation [Rule 8(5)], mandatory individual and public sale notices [Rule 8(6)], and public e-auction parameters [Rule 9(1)].⁴

3. REVIEW OF LITERATURE

Since the inception of the SARFAESI Act, 2002, have generated a substantial volume of legal and economic literature. Academics, regulatory bodies,

³ *Mardia Chemicals Ltd. v. Union of India*, (2004) 4 SCC 311.

⁴ The Securitisation and Reconstruction of Financial Assets and Enforcement of Security Interest Act, 2002, § 8,9,13,14, No. 54, Acts of Parliament, 2002 (India).

² Security Interest (Enforcement) Rules, 2002, Gazette of India, pt. II sec. 3(i) (ext.) (Nov. 18, 2002).

and legal jurists have extensively analysed the socio-economic impacts of bypassing judicial intervention in debt recovery matters. This review synthesizes existing literature into three core thematic domains.

3.1. Institutional Power Imbalance-The Shift to Non-Judicial Debt Recovery:

Prior to 2002, the recovery of distressed banking assets under the Recovery of Debts Due to Banks and Financial Institutions (RDDBFI) Act, 1993, was widely critiqued for institutional paralysis and excessive procedural delays. Legal scholars argue that the introduction of the SARFAESI Act was a necessary macroeconomic imperative designed to restore liquidity to a crippled banking sector by establishing non-judicial enforcement.⁵

However, early critical literature flagged the dramatic shift in power dynamics. Researchers have observed that by making the secured creditor an adjudicator in its own cause under Section 13(2), the legislature stripped away vital pre-enforcement procedural shields, introducing an unprecedented vulnerability into the enforcement framework. Critics assert that the complete absence of independent administrative screening during the demand and repossession phases paved the way for institutional overreach, transforming what was intended as an economic remedy into a tool susceptible to bureaucratic arbitrariness.⁶

3.2. Systematic Vulnerabilities and Procedural Misuse:

More recent legal scholarship focuses on the precise operational modalities where the SARFAESI process is systematically misused. Legal literature identifying corporate and institutional malpractices highlights a recurring pattern of collusive fraud between financial institution's officials and corrupted authorized officers, and preferred external bidding cartels. Commentators emphasize that the lack of transparent, independent oversight over the fixation of the "reserve price" under Rule 8(5)

⁷frequently leads to the deliberate undervaluation of properties, directly violating the borrower's constitutional right to property under Article 300A.⁸

Conversely, banking literature and regulatory reports published by the Reserve Bank of India (RBI) highlight the widespread issue of borrower-led litigation fraud. Academic papers document how defaulting borrowers aggressively exploit the "rent control" loophole by generating sham, unregistered, and backdated lease agreements. Authors demonstrate that these fraudulent tenancies are strategically constructed to frustrate the execution of Section 14 physical possession orders by District Magistrates, thereby devaluing repossessed collateral and freezing bank capital in prolonged litigation.

3.3. The Dynamic Boundaries of Judicial Correction:

The evolution of judicial review from a passive post-facto mechanism to an active constitutional regulatory force forms the third major pillar of existing research. Early legal commentaries focused heavily on the landmark ruling in *Mardia Chemicals Ltd. v. Union of India* (2004), praising the Supreme Court for striking down structural barriers to access justice, such as the initial 75% pre-deposit requirement.⁹

Subsequent literature tracks a distinct shift in judicial philosophy. Contemporary scholars argue that while the judiciary initially leaned toward protecting borrower equity and enforcing strict natural justice—as seen in **Mathew Varghese (2014)** courts have recently pivoted toward an approach of structural self-restraint. Modern legal reviews of Supreme Court jurisprudence note an aggressive institutional pushback against the misuse of constitutional writ jurisdictions under Article 226. Legal analysts conclude that the current judiciary is attempting to forge a highly complex, equilibrium-based standard: creating a strict barrier against alternative-remedy forum shopping by

⁵ The Recovery of Debts Due to Banks and Financial Institutions Act, 1993, No. 51, Acts of Parliament, 1993 (India).

⁶ Security Interest (Enforcement) Rules, 2002, Gazette of India, pt. II sec. 3(i) (ext.) (Nov. 18, 2002).

⁷ Security Interest (Enforcement) Rules, 2002, Gazette of India, pt. II sec. 3(i) (ext.) (Nov. 18, 2002).

⁸ India Const. art. 300A.

⁹ *Mardia Chemicals Ltd. v. Union of India*, (2004) 4 SCC 311.

borrowers while simultaneously demanding total, uncompromised compliance with statutory timelines from secured financial institutions.¹⁰

4. INCIDENCES OF THE PROVEN FRAUDS COMMITTED BY THE BANKS WITH SOME CASE EXAMPLES.

Wrongdoing claims under SARFAESI often point to abuse of power, twisted facts, or secret deals with outsiders - rarely just small errors. Such matters typically unfold through harsh legal battles at Debt Recovery Tribunals or via probes launched by law enforcement agencies.

Here come some real cases where courts or regulators spotted sketchy moves. One time, fake invoices showed up in company books. Another case involved shifting money between accounts to hide losses. A firm once sold shares without telling buyers about serious risks. In one report, insiders got early tips before public announcements. False customer numbers appeared in a quarterly filing. Payments were rerouted through shell firms during an audit. Officials later caught altered contracts in a bankruptcy review

4.1. Collusive Fire Sales and Under-pricing of an assets of debtors.

This has been a consistent issue with banks being accused of colluding with valuers and prospective buyers to sell assets at a significantly lower price than they are worth in the market.

Example Case: The case is connected with **Mathew Varghese v. M. Amritha Kumar (2014) principles.** (Chand, n.d.)¹¹

Although the decision was directly about compliance with the various procedures with respect to the notice periods, most of the underlying cases in the DRT level have express claims of rigged auctions.

The Allegation: Borrowers claim that the bank is manipulating the reserve price by employing

biased or unqualified valuers, who are giving artificial low estimates. In the e-auction, inadequate publicity is provided so that only a few prospective bidders, usually with bank connections are notified about the sale.

The Result: DRTs are allowed to void the sale in the case of the production of evidence of gross undervaluation (e.g. the sale of a 1 crore property at 50 lakh) and the bank is obliged to re-auction the property after following the prescribed proper, transparent regulations.

4.2. Incorrect Tiering of Borrowers to evade Protection.

There have been allegations that banks have been categorizing borrowers knowingly through misclassifying them to avoid legal timelines and notifications.

Sample Case: M/S Pro Knits Vs Board of Directors of Canara Bank and Others.¹²

With analysis by advocacy groups and legal commentary, certain banks are claimed to ignore the regular 17 months to move an MSME account to a Non-Performing Asset (NPA) and then to a Doubtful/Loss.

The Accusation: Banks occasionally preemptively declare a routine business NPA into a "wilful defaulter" based on unspecified and/or fabricated reports (e.g. the borrower embezzled funds without actual evidence). This misclassification is applied in order to take instantaneous and severe steps under the SARFAESI Act without a prerequisite of 60 days' notice as in Section 13(2).

The Result: Should the borrower be able to demonstrate in the DRT that the wilful defaulter status was unwarranted or was not formulated in good faith, it can be said that the whole SARFAESI process can be abridged or halted as an abuse of natural justice.

¹⁰ *Mathew Varghese v. M. Amritha Kumar*, (2014) 5 SCC 610.

¹¹ *Mardia Chemicals Ltd. v. Union of India*, (2004) 4 SCC 311.

¹² [M/S. PRO KNITS v. THE BOARD OF DIRECTORS OF CANARA BANK | Supreme Court Of India | Judgment | Law | CaseMine](#)

4.3. Manipulation of Titles and Mortgages Frauds.

In some of the complex cases concerning third parties, the courts have found instances in which the formation of the mortgage itself was founded upon fraudulent conduct by many persons including the bank workers.

Courts involved: Punjab National Bank Vs. Gauhati High Court (2022).¹³

In the current case, a plaintiff alleged that a loan and mortgage was formed between PNB and another defendant which was a fraudulent mortgage formed by the defendant to defraud and mislead the plaintiff.

The Allegation: The plaintiff also claimed that the bank had authorised a loan without due diligence on the title of the property and that the dealings were collusive. The High Court noted that it was necessary to investigate allegations of fraud committed between the respondent No. 2 and the petitioner Bank between each other.

The Ruling: The court upheld the fact that allegations of a complex fraud on title and mortgage validity is within the jurisdiction of a Civil Court, as opposed to only the DRT, by enabling the aggrieved party to have a full trial and reveal the alleged fraud.

4.4. Conspiracy in Promoting Assets to ARCs.

Criticisms are also raised where the banks choose to sell an NPA to an Asset Reconstruction Company (ARC) instead of making a One Time Settlement (OTS) with the original lender.

The Accusation: The critics say that banks prefer ARCs (that purchase loans at deep discounts, usually approximately 85 cents on the dollar) ¹⁴to an OTS that could result in better recovery to the bank. Such non-transparent preference creates doubts of collusion or systematic prejudice that is akin to shortchanging the borrower and limiting the opportunity to

recover the greatest amount of funds in the community.

The Resultant Consequence: Although commercial decisions are much in the prerogative of the bank, such practices have prompted regulatory requests that the OTS option should be fully exhausted before an asset is sold to an ARC.

4.5. The Right of Redemption Lingers on to the Last Phase.

The most frequent example of judicial intervention that I have encountered was safeguarding a borrower in their right of redemption at a very late stage as long as the bank had not finalized the legal sale of them.

G. V Vikram Kumar vs Authorised Officer, Indian Bank (Supreme Court, 2023)¹⁵:

The court determined that the right of a borrower to redeem the secured asset applies until the transfer of the property actually takes place i.e. until the issuance of the sale certificate, its registration, and delivery of the possession. They emphasized that the bank is not allowed to supersede this right in case the borrower pays the entire sum before the sale has been legally finalized.

4.6. Absence of Due Diligence of Property Titles.

In other cases, banks have been subjected to bitter criticisms and negative adjudications due to their inability to perform due diligence regarding titles of properties that they take as a security which can indicate negligence, or even willful blindness.

P. Satyanarayana vs Smt. V. Anjana (Telangana High Court, 2025)¹⁶:

The plaintiff of this case argued that various defendants, one of them a bank, had conspired to generate forged documents so as to deny her the possession of her property.

¹³ [Page No.# 1/3 vs The Punjab National Bank And Anr on 26 September, 2022](#) by India Kanoon.

¹⁴ [Asset Reconstructions Companies: Asset Reconstruction Companies Boost Recovery on Unsecured Loans amid Bank Caution, ETBFSI](#)

¹⁵ [THE AUTHORIZED OFFICER, v. GOPAKUMAR T | Kerala High Court | Judgment | Law | CaseMine](#)

¹⁶ E Newsletter Telangana Highcourt
10_31T13_15_22VOLUME_7_ISSUE_NO_1_FOR_THE
_PERIOD_OF_01_01_2025_TO_31_03_2025.pdf

The Allegation: The bank was charged with lending money without conducting the necessary procedures in terms of verifying the property.

The Ruling: The court permitted the civil action to be commenced, which means that the complicated fraud and title claims have to be resolved by a qualified civil court as it is not under the summary jurisdiction of the DRT.

4.7. Violation of Statutory First Charges.

Borrowers (and other parties) have been safeguarded by courts when the banks are seeking to recover their debts by defeating rules that are statutory in that they take priority over all their claims.

Jalgaon District Central Coop. Bank Ltd. vs. State of Maharashtra and ors. (Supreme Court, 2025)¹⁷:

According to the decision of the Supreme Court, the priority of the secured creditors granted by Section 26E of the SARFAESI Act is lower than a statutory first charge established as per Section 11(2) of the EPF and MP Act in respect of dues of a provident fund.

The Result: This ruling safeguards the employers/borrowers to the banks that they must surrender their assets to allow them to pay the essential statutory obligations, and a bank cannot claim that it has an overall priority when the law declares it otherwise.

4.8. Lack of Jurisdiction of Civil Court in Fraud Cases.

Although Section 34 of the SARFAESI Act is quite categorical against civil suits, the courts have provided a loophole in the case of actual, institutionalized fraud.

Aavas Financiers Ltd. Vs. Smt. Bhagwanti Mahawar (Madhya Pradesh High Court, 2023):¹⁸

¹⁷ [EPF First Charge vs SARFAESI Section 26E Priority: Commentary on Jalgaon District Central Coop. Bank Ltd. v. State of Maharashtra: Supreme Court Of India | CaseMine](#)

¹⁸ [AAVAS FINANCIERS LIMITED v. BHAGWANTI MAHAWAR | Supreme Court Of India | Judgment | Law | CaseMine](#)

The High Court in its ruling stated that the Civil Court has the jurisdiction over the action of the secured creditor in case the latter is alleged to be fraudulent. The court also pointed out that when a suit has been initiated based on particular pleas of fraud and deceit by the bank, the same can be upheld, provided that the principle of the initial landmark case of Mardia Chemicals.

4.9. Sale of Mortgaged Properties to Particular Debts.

The courts have also barred the banks to fraudulently use their general lien powers to foreclose property of a particular loan to collect unrelated liabilities.

Nand Kumar Adil Vs. State Bank of India (Chhattisgarh High Court, 2023)¹⁹:

The Court decided that where title deeds of a property had been presented as security to a particular term loan, a general power of lien under Section 171 of the Contract Act could not be used by the bank to assert security over the property in relation to other and unrelated amounts of loan.

The Ruling: Court determined that the bank had not exercised reasonable cause in exerting general lien which is occasionally manipulatively applied to gain a greater leverage over the borrower.

Court cases pointing to bank fraudulent practices in the implementation of SARFAESI Act are typically focussed on such severe procedure impropriety as collusion in the sale process, gross understatement or record manipulation. This is frequently contested in the Debt Recovery Tribunals (DRT) or underlying criminal complaints (CBI/Police) and the courts grant relief in situations where fraud, or material irregularity, is established.

4.10. The Sale of Assets at a Pittance (Gross Underestimation).

There have been several instances where the courts have intervened on the basis that the reserve price offered by the bank and the final auction price are evidently lower than the fair market value hence, an indication of a non-transparent process.

¹⁹ [Nand Kumar Adil Vs. State Bank of India – Chhattisgarh High Court – IBC Laws.](#)

Case Principle: Sales have been rejected in several cases of DRT and High Court proceedings in accordance with the principles of **Mathew Varghese v. M. Amritha Kumar (2014)**.²⁰

The Incidence: Borrowers have proven through independent valuation reports that their property was highly much more than the value that it received at a bank auction. The determination by the court that the bank did not provide adequate publicity or applied an artificial low reserve price usually demonstrates the possibility of fraud or a material irregularity to void the sale.

Judicial Result: The courts declare that, although the bank had the power to sell the asset, it had an obligation to the borrower to sell the asset at the most desirable price. The inability to do so amounts to misusing the provisions of the Act.

4.11. Material Facts Hiding During Auction.

Banks have been sued on grounds of having hidden key information about the secured property to the potential buyers during the auction.

Facts: A police officer was on patrol when he approached a vehicle and discovered both occupants were being loud and abusive toward one another.

Case Instance: Authorised Officer v. Brahmo Construction Pvt. Ltd. (2014)²¹

The Incidence: The initial incidence in this particular case was the allegations of deceit by the bank on the part of the initial auction buyer. It is also claimed that the bank had secretly hid the fact that the property was in statutory attachment by the Income Tax Department, at the time of the auction.

Judicial Ruling: The Trial Court in this case ruled that a case on fraud put a matter within the jurisdiction of the Civil Court despite the bar established under Section 34 of the SARFAESI Act. Such a ruling suggests that the civil action may be pursued in cases that are associated with

the bank activities that include deception, and concealment of material facts.

4.12. False Representation and Fraud of Documentation of Loans.

Borrowers have filed police complaints and civil suits in addition to DRT applications when they claim that their documents or title deeds have been used without their knowledge or with other purposes of loan that had been agreed upon.

Case Facts: Tajunissa and Anr. Vs. Mr. Vishal Sharma and Ors. (Delhi High Court, 2022)²²

The Incidence: On behalf of the plaintiffs, they have claimed that the co-defendant, in conspiracy with the bank officials, acted with their property title deeds and forged documents to take a big loan with the bank. The plaintiffs asserted that they were never aware of the mortgage until recovery notices were made.

Judicial Determination: The High Court did not dismiss the case because it passed judgment that such grave fraud claims of third parties and the possibility of bank collusion were subject to a complete judicial inquiry and not just regular SARFAESI litigation.

4.13. Evading Statutory Requirements of Possession.

Although it is not always referred to as a "fraud," banks which have tried to seize possession without following very strict preconditions do not succeed and are overturned by the courts.

Case scenario: IDFC First Bank Ltd. Vs. State of Haryana and others (Punjab and Haryana high court, 2022).²³

The Incidence: At a time when the bank in this instance was trying to enforce a Section 14 order, there are regular cases where the banks have assumed possession without necessarily following all the legal requirements. The credit was given free will to take further steps since the former proceedings had been invalid.

Court Result: The courts take the necessary steps in ensuring that the high standards outlined in the Act are exercised only when the letter of the law is adhered to, as it offers a relief to the

²⁰ Supreme Court of India-CIVIL APPEAL NO. 12174 OF 2025, CIVIL APPEAL NO. 12175 OF 2025[Special Leave Petition (Civil) No. 14696 of 2023

²¹ [Legal Implications of Selling Mortgaged Property to Third Parties](#)

²² [Tajunissa & Anr. vs Mr. Vishal Sharma & Ors. on 4 January, 2022](#)

²³ [Idfc First Bank Limited vs State Of Haryana And Others on 13 December, 2022](#)

borrowers in the times when the banks cut corners or they are misusing the possession process.

5. FINDINGS OF THE STUDY

Unfair and Unlawful Practices by Financial Institutions

5.1. Malicious Undervaluing of Assets and Arbitrary Reserve Pricing: A primary finding is that authorized officers frequently abuse their valuation powers under Rule 8(5). Banks often collude with empanelled property valuers to fix the "reserve price" of secured assets drastically below their actual market value or prevailing circle rates. This artificial distress pricing allows banks to execute rapid liquidations to favoured or cartelized buyers, destroying the borrower's asset equity and violating their constitutional right to property under Article 300A.²⁴

Case Example: In *Raj Pal v. PNB Housing Finance Ltd.* (2008), the court struck down an auction sale because gross, systematic undervaluation and institutional bad faith in fixing asset pricing completely vitiated the legality of the recovery process.²⁵

5.2. Surreptitious Bypassing of Mandatory Notice Timelines: The paper finds that secured creditors routinely treat the mandatory 30-day individual and public notice requirements under Rules 8(6) and 9(1) as mere administrative formalities rather than non-negotiable statutory safeguards. Financial institutions frequently rush to hold public auctions on short notice, explicitly aiming to prevent borrowers from exercising their statutory right of redemption or approaching the Debt Recovery Tribunal (DRT) for an interim stay.

Case Example: In the landmark ruling *Mathew Varghese v. M. Amritha Kumar* (2014), the Supreme Court heavily penalized a bank for executing an auction without strict timeline compliance. The Court held that rushing an asset sale without the mandatory 30-day notice is a

structural fraud upon the law, rendering the entire transaction an absolute nullity.²⁶

5.3. Procedural Perjury and Fabrication of Timelines to avoid the liability: The study reveals that financial institutions occasionally resort to active evidentiary fraud. When facing the strict deadlines of the SARFAESI Act, authorized officers have been caught retroactively forging postal dispatch receipts, manipulating courier tracking records, or backdating newspaper advertisement dates to manufacture a false paper trail of statutory compliance.

Case Example: In *Mardia Chemicals Ltd. v. Union of India* (2004), while the Supreme Court upheld the Act's overall validity, it explicitly built in the requirement for banks to meaningfully reply to borrower objections under Section 13(3A) to stop banks from operating with complete procedural arbitrariness and fabricating compliance.²⁷

5.4. Abuse of Section 14 Machinery through Misleading Affidavits in CMM Courts, DM office: To bypass the resistance of a defaulting borrower, financial institutions aggressively utilize the administrative machinery of Section 14. The paper finds that banks routinely commit perjury by submitting false or misleading Nine-Point Affidavits to the District Magistrate (DM) or Chief Metropolitan Magistrate (CMM). They systematically conceal pre-existing legal disputes, ongoing civil litigations, or severe structural defects in the asset's title simply to secure swift physical possession orders.

Case Example: In recent jurisprudence clarifying Section 14, courts have established that while the DM/CMM cannot adjudicate the validity of the loan, they must refuse administrative assistance if the bank's affidavit is found to contain fraudulent or misleading statements.²⁸

²⁴ India Const. art. 300A.

²⁵ *Raj Pal v. PNB Housing Finance Ltd.*, 2008 (3) LH (P&H) 2556.

²⁶ *Mathew Varghese v. M. Amritha Kumar*, (2014) 5 SCC 610.

²⁷ *Mardia Chemicals Ltd. v. Union of India*, (2004) 4 SCC 311.

²⁸ The Securitisation and Reconstruction of Financial Assets and Enforcement of Security Interest Act, 2002, § 14, No. 54, Acts of Parliament, 2002 (India).

5.5. Arbitrary Evictions and Coercive Force Against Bona Fide Tenants:

Financial institutions regularly employ coercive strong-arm recovery tactics, completely ignoring the statutory protections granted to legitimate third parties. Instead of taking lawful, symbolic possession of properties occupied by valid, long-term lessees, banks use recovery agents to forcefully and physically evict residents, flagrantly violating state rent control legislations.

Case Example: In *Harshad Govardhan Sondagar v. International Assets Reconstruction Co. Ltd.* (2014), the Supreme Court clamped down on this institutional practice. The Court ruled that financial institutions cannot use the SARFAESI Act as a blunt instrument to trample upon legitimate, pre-existing third-party real estate rights, ordering that valid tenancies must be legally respected until their expiration.²⁹

6. RECOMMENDATIONS

To address the systematic vulnerabilities, institutional overreach, and procedural lapses identified in the implementation of the SARFAESI Act, 2002, the framework must undergo structural reforms. The following recommendations provide strategic suggestions to establish transparent **fair practices**, **fortify regulatory prospectuses**, and guarantee the comprehensive **protection of borrowers' rights**.

6.1. Reforms for Prospectus Transparency & Independent Valuation of assets.

- **Requirement of Mandatory Multi-Agency Valuation Audits:** To eliminate the malicious undervaluation of secured assets, the law should mandate that the "reserve price" under Rule 8(5) be determined by an average of two independent, government-approved institutional valuers.
- **Use of Blockchain E-Auction Portals:** Financial institutions must move away from isolated, bank-managed digital auctions. A unified national e-auction platform backed by blockchain technology should be introduced to publicly log all bid histories, preventing cartelization, proxy bidding, and the

retroactive tampering of bid timelines by authorized officers.

● **Comprehensive Disclosure in the Auction**

Prospectus: The sale prospectus issued by the bank must transparently disclose any "clouds on the title," pending litigation, structural defects, or existing third-party tenancy claims. Selling an asset on an "as-is, where-is" basis should not exempt a financial institution from the tort of fraudulent concealment.

6.2. Structuring Fair Practices Modul for Financial Institutions

- **Strict Digital Logging of Statutory Notices:** To stop the fabrication of procedural timelines, the dispatch of the mandatory 60-day demand notice [§ 13(2)] and the 30-day auction notice [Rule 8(6)] must be integrated into a secure, third-party electronic registry. This registry would serve as definitive, unalterable proof of service for the Debt Recovery Tribunal (DRT).

- **Reasoned and Mandatory Adjudication of Objections:** Financial institutions must move beyond issuing boilerplate rejections to borrower objections under Section 13(3A). The authorized officer should be statutorily required to provide a detailed, "reasoned order" addressing every specific material objection raised by the borrower. Failure to provide a reasoned reply should automatically halt subsequent Section 13(4) measures.

- **Codified Code of Conduct for Recovery Agents:** A strict, statutory code of fair practice must govern bank-paneled recovery agents. The use of coercive or strong-arm physical eviction tactics outside the precise administrative order of a Section 14 Magistrate must lead to immediate financial penalties on the bank and criminal prosecution of the offending individuals.

6.3. Enhanced Protection of Borrowers' and Third-Party Rights

- **Statutory Expansion of the Right of Redemption:** Following the spirit of *Mathew Varghese (2014)*, the statutory right of redemption under Section 13(8) should be explicitly extended up to the exact moment the auction transfer deed is registered, rather than

²⁹ *Harshad Govardhan Sondagar v. International Assets Reconstruction Co. Ltd.*, (2014) 5 SCC

terminating upon the publication of the auction notice. This provides the borrower with a final, uncompromised opportunity to salvage their property.

- **Summary Screening Mechanism Under Section 14:** While the role of the District Magistrate under Section 14 is administrative, a mandatory "Notice to Occupant" rule must be codified. Before executing a physical eviction order, the Magistrate must provide a brief, 15-day window for any third-party resident to present a registered lease or utility bills, operationalizing the protective guidelines laid out in *Harshad Govardhan Sondagar (2014)*.

- **Accountability and Penalties for Perjury:** If a bank is found to have submitted a false or misleading Nine-Point Affidavit under Section 14, or is found guilty of structural fraud during post-facto review under Section 17, the DRT must have the statutory power to levy exemplary damages on the financial institution and initiate mandatory disciplinary action against the authorized officer.

7. CONCLUSION:

The Securitisation and Reconstruction of Financial Assets and Enforcement of Security Interest (SARFAESI) Act, 2002, was undeniably an economic necessity. It rescued the Indian banking sector from structural stagnation by establishing an expedited, non-judicial debt recovery architecture. However, this study demonstrates that removing prior judicial intervention has inadvertently exposed the enforcement process to severe bad-faith manipulation. The findings reveal a disturbing dual vulnerability: a top-down threat characterized by institutional overreach, malicious property undervaluation, and the manipulation of timeline notice constraints by secured creditors; and a bottom-up threat driven by defaulting borrowers who exploit regulatory gray areas through fabricated tenancies and anti-competitive e-auction cartelization. In this environment of conflicting malpractices, the evolution of judicial control has proved essential. From the landmark intervention in *Mardia Chemicals* to modern rulings like *Phoenix ARC*, the Indian judiciary has continually recalibrated its stance. It

maintains a dual responsibility: aggressively policing the procedural integrity of asset liquidations to protect individual constitutional rights under Article 300A, while firmly blocking frivolous, obstructionist writ petitions from choking specialized tribunals like the DRT. Ultimately, judicial control shouldn't have to carry the burden of correcting basic structural flaws in the law. For the SARFAESI Act to achieve its primary economic purpose without compromising systemic fairness, the legislative and regulatory frameworks must evolve. Implementing blockchain-backed central e-auction registries, mandating multi-agency asset valuation audits, and strictly enforcing penalties for procedural perjury will bridge the gap between financial efficiency and natural justice. Only through these structural changes can the SARFAESI Act transform from a potentially arbitrary tool of administrative power into a mature, equitable, and transparent mechanism for national economic recovery.

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Charging and Control Circuits for Lithium-Ion Batteries in Electric Vehicles: An Overview

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ABSTRACT

The increasing adoption of electric vehicles (EVs) has created a growing need for efficient, reliable, and safe battery charging systems. Lithium-Ion batteries are widely used in EVs because of their high energy density, long cycle life, and fast charging capability. However, their performance and lifespan depend significantly on the charging method employed. This work presents the design and development of an SMPS-based battery charger using the Constant Current–Constant Voltage (CC–CV) charging technique for a 36 V (10S) Lithium-Ion battery pack. The proposed charger converts a single-phase AC supply into a regulated 42 V DC output with a maximum charging current of 7.5 A. A buck converter controlled by Pulse Width Modulation (PWM) is used to achieve high conversion efficiency, while a MOSFET serves as the primary switching device. A relay driver circuit is incorporated to protect the battery from reverse charging and enhance operational safety. The charging process is controlled by a Raspberry Pi, which continuously monitors battery voltage and charging current and automatically switches from constant-current mode to constant-voltage mode as the battery reaches its rated voltage. This intelligent control strategy improves charging efficiency, reduces overheating, and helps extend battery life.

The charger is designed, modeled, and analyzed using MATLAB/Simulink, followed by converter design, component selection, thermal analysis, and hardware implementation. Simulation and experimental results demonstrate that the proposed charger provides stable operation, improved power quality, high efficiency, and reliable charging performance. The developed system offers a practical, cost-effective, and scalable solution for modern electric vehicle charging applications.

Introduction

In recent years, electric vehicles (EVs) have gained significant attention worldwide due to their potential to reduce carbon emissions, decrease dependence on fossil fuels, and promote sustainable transportation. As the adoption of EVs continues to grow, the demand for efficient, reliable, and safe battery charging systems has increased considerably. However, long charging times and limited driving range, commonly referred to as range anxiety, remain major challenges that hinder the widespread adoption of electric vehicles. [1]

The battery charger is one of the most critical components of an electric vehicle, as it directly affects charging efficiency, battery life, and overall vehicle performance. Most public charging stations provide a single-phase AC power supply, which is converted into the required DC voltage by an onboard Switched-Mode Power Supply (SMPS) charger. In India, commercially available onboard chargers typically have power ratings ranging from 2.5 kW to 3 kW and operate from a 230 V single-phase AC supply. These chargers are designed to provide efficient power conversion while ensuring safe and reliable battery charging. [2]

Lithium-Ion batteries have become the preferred energy storage technology for modern electric vehicles because of their high energy density, long cycle life, low self-discharge rate, and excellent charging performance. However, the efficiency, safety, and lifespan of these batteries depend largely on the charging method employed. [3] Several charging techniques have been developed for Lithium-Ion batteries, including Constant Trickle Charging (CTC), Constant Current (CC), Constant Voltage (CV), and Constant

Current-Constant Voltage (CC-CV) charging. Among these methods, the CC-CV charging technique is widely recognized as the most effective because it enables faster charging while minimizing the risks of overcharging, overheating, and battery degradation. [4], [5]

The novelty of this research lies in the design and development of a digitally controlled SMPS-based CC-CV battery charger for a 36 V (10S) Lithium-Ion battery pack using a Raspberry Pi as the main controller. Unlike conventional battery chargers that rely on analog control circuits or dedicated charging integrated circuits, the proposed charger employs a programmable Raspberry Pi to implement an intelligent CC-CV charging algorithm. The controller continuously monitors the battery voltage and charging current and automatically switches between the constant-current and constant-voltage charging modes to ensure safe and efficient charging. Furthermore, the proposed system incorporates a PWM-controlled buck converter with a MOSFET-based switching circuit and a relay driver to provide reverse-polarity protection, thereby enhancing the safety and reliability of the charger.

The complete system is modeled and analyzed in MATLAB/Simulink, followed by hardware implementation and experimental validation. The proposed charger demonstrates improved charging efficiency, better power quality, reliable operation, and enhanced battery protection. In addition, its digital control architecture provides a flexible and scalable platform that can be extended to support advanced Battery Management System (BMS) functions, real-time monitoring, data logging, and IoT-enabled smart charging applications. These features make the proposed charger a practical and cost-effective solution for next-generation electric vehicle charging systems.

Literature Review

Abdulkarim Nasir et al. [1] proposed the design of a Constant Voltage–Constant Current (CVCC) fast battery charger for electric vehicles. Their study reviewed several AC–DC fast charging topologies, including PWM rectifiers, NPC Vienna rectifiers, and buck converters. After discussing the limitations of existing charging systems, the authors developed a DC–DC buck converter-based charger employing the CVCC charging technique to achieve efficient and reliable battery charging.

Prasad Vijay Yadav et al. [2] developed a robust Switched-Mode Power Supply (SMPS) battery charger for Lithium-Ion batteries and incorporated several protection mechanisms to improve charging safety. The proposed charger was based on a forward converter topology, with the output voltage regulated through a feedback control system. The authors also presented a detailed simulation model featuring a wide input voltage range, a window comparator, a soft-start circuit using a totem-pole comparator, and a PWM controller for effective converter operation.

H. A. Hidayah and M. Somantri [3] investigated a fast-charging system based on a high-current charging technique. Their design employed a rectifier circuit, a buck converter, and an Atmega microcontroller to regulate the charging process. Experimental results showed that the proposed approach increased the charging current, thereby reducing the overall battery charging time.

Mahesh Sharma [4] presented a microcontroller-based charger for Lithium-Ion batteries and identified the Constant Current–Constant Voltage (CC–CV) charging technique as the most suitable method for Li-Ion battery charging. The proposed charger was implemented using an 89S52 microcontroller, providing accurate charging control and improved battery protection.

L. Chitra et al. [5] proposed two different approaches for charging electric vehicles: Grid-to-Vehicle (G2V) and Solar-to-Vehicle (S2V) charging. Their work demonstrated that EV batteries can be charged either from a conventional

single-phase grid supply or through renewable energy generated by photovoltaic solar panels, thereby supporting environmentally friendly charging solutions.

Rutvi T. Vora et al. [6] provided a comprehensive review of charging and control circuits used in electric vehicles. The paper explained the operation of each section of the charging system, from power conversion to battery control, and discussed several charger design approaches suitable for EV applications.

Hidayah H. A. et al. [7] presented the design and implementation of a fast battery charging control system using an Atmega32 microcontroller. The proposed controller dynamically adjusted the charging current according to the battery condition and circuit requirements, resulting in improved charging efficiency and reduced charging time. Experimental results demonstrated that the system significantly increased the charging current while maintaining battery safety and reliability.

Prasad Vijay Yadav et al. [8] developed and experimentally validated an SMPS-based battery charger for Lithium-Ion batteries used in electric vehicles. The charger continuously monitored the battery voltage and gradually reduced the charging current as the battery approached full charge using a PWM controller. This intelligent charging strategy minimized battery stress, improved battery life, and ensured safe and complete charging. The developed prototype demonstrated reliable performance and was found to be suitable for electric two-wheelers.

Abdulkarim Nasir et al. [9] presented the design, simulation, and experimental validation of a Constant Current–Constant Voltage (CC–CV) fast battery charger for electric vehicles. The proposed charger consisted of a three-phase controlled rectifier, a DC–DC buck converter, and a battery charging unit. A Voltage-Oriented Control (VOC) strategy based on direct–quadrature (d–q) control was employed to regulate the rectifier. The charging controller implementing the CC–CV algorithm was modeled and analyzed using MATLAB/Simulink. The hardware prototype was developed using an Arduino Nano microcontroller,

a buck converter, and a current sensing circuit, and it was tested with both lead-acid and Lithium-Ion batteries. The experimental results confirmed the effectiveness of the proposed charger in achieving efficient and reliable battery charging.

A review of the existing literature indicates that significant progress has been made in the development of battery chargers for electric vehicles. Most researchers have focused on improving charging efficiency through different converter topologies, charging algorithms, and microcontroller-based control systems. However,

many of these studies rely on conventional controllers such as the Atmega series or Arduino platforms and primarily emphasize simulation or prototype development. These observations highlight the need for a more flexible and intelligent charging system capable of delivering efficient CC–CV charging with enhanced control, monitoring, and safety features. This research addresses that need by developing a Raspberry Pi-based SMPS charger that combines digital control, efficient power conversion, and practical hardware implementation for modern electric vehicle applications.

Table 1: Types of Chargers

Specifications/Parameters	Level 1	Level 2	Level 3
Working Voltage	110/120V	208/220/240V	AC 3-Phase,400V
Current Capacity	12-16Amp	12-80Amp	<125Amp
Power Output	3.6KW	7.6KW	50-1000KW
Range	2-5 Miles/hrs.	10-30 Miles/hrs.	50-100 Miles/hrs.
Charging Time	10-12 hrs.	4-8hrs.	30min-2hrs.

Comparison of different ac/dc topologies for fast dc chargers

Popular converter topologies used in EV battery chargers are PWM converters, NPC converters, Vienna converters and Buck type converters.

Pulse Width Modulation Converter (PWM):

PWM converter controls the output voltage or current by adjusting the width of pulses. It also converts average power delivered to the load. Such devices are used in inverters and DC TO DC converters.

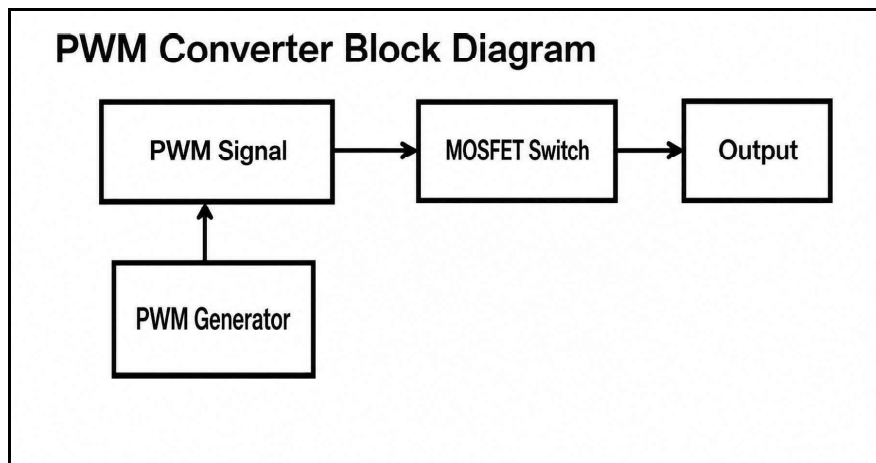


Figure 1: PWM convertor block diagram

PWM Devices use MOSFETS or IGFETS as a high speed switching devices where the duty cycle decides the average output voltage. Higher duty cycle means MOSFET is ON for a longer time on the other hand lower duty cycle means MOSFET is ON for a shorter duration. In this way the duty cycle controls the output voltage. Hence PWM converters are used in DC to DC converters. PWM converters are highly efficient and they have precise control over output voltage and current. They are also able to minimize the harmonic distortions in the output waveform.

Neutral Point Clamped Converter (NPC) : This design is suited for higher voltage output. Clamping diodes allows to handle higher input voltages. Hence they are specially used in medium and high voltage applications. For battery vehicles they are used in onboard chargers.

Vienna Converters:

Vienna converter is a popular 3 phase AC to DC converter. It is a unidirectional 3 phase PWM rectifier. They are highly efficient and able to

produce very low harmonic distortion. In AC switching circuits the Vienna rectifier is used as a boost converter. In Electric Vehicle chargers Vienna converts are used in vehicle to grid (V2G) technology.

Buck type Converters:

Buck converter is a DC to DC converter which converts high input to a low voltage output. Switching devices used to reduce the voltage are Diode, Capacitor, Inductor, MOSFETS etc. by Buck converters.

Diode is a unidirectional device which flows current when it is forward biased. The capacitor provides stable voltage by reducing ripples. The inductor stores the energy when it is ON and reduces the output voltage and increases the output voltage when it is OFF. Thus provides constant voltage at the output. MOSFET is a very fast device to make input voltage ON and OFF maintains the output voltage constant also. Efficiency for buck regulators is about 90% **or more.**

DESIGN OF FAST CHARGING CIRCUIT

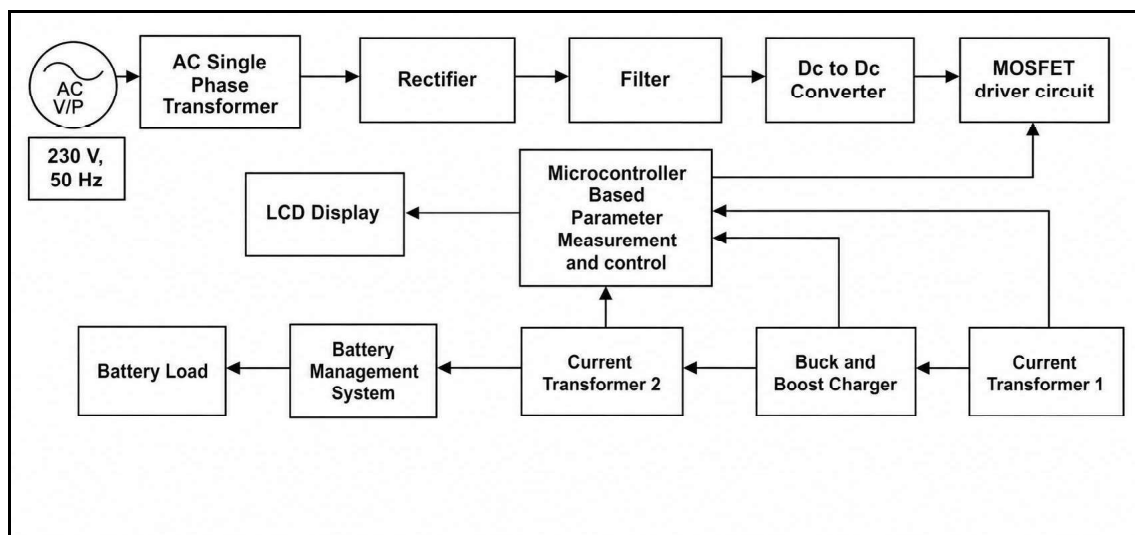


Figure 2: Block diagram of fast charging circuit

Buck Converter Circuit

Buck converter circuit converts DC-DC voltage which is variable. This circuit uses Pulse Width

Modulation (PWM) technique which is nothing but a continuous ON/OFF switch and duty cycle to control the speed of switch.

MOSFET Driver Circuit

MOSFET driver circuit communicates between the microcontroller and a buck converter acts as a separator between power circuits with control circuit. Which protects the microcontroller from voltage behind the buck converter.

Relay Circuit

The relay circuit connects and disconnects the voltage from the voltage source to the battery fast charging circuit set by the microcontroller. Input of relay circuit is adjusted from voltage and current sensors.

Voltage detector

This voltage divider circuit works for voltage divider or voltage sensor circuit, because microcontroller system cannot accept voltage more than 5 volts and the circuit can measure larger DC voltage of 48V – 54V to 0V – 5V.

Current sensor circuit

The current sensor works for a safety and monitoring current which is flowing towards battery charging circuit.

Selection of Microcontroller

The Microcontroller is the brain of the battery charging system. One can select suitable microcontroller like PIC, Arm, Arduino, Atmega 32, 89S52, Raspberry pie etc. Prior choice is made as the role of Microcontroller is very vital.

Role of Raspberry Pi:

In the provided setup (ev_charger_ui.py running on a Raspberry Pi with I²C peripherals ADS1x15 and MCP4725, Kivy touchscreen UI, and GPIO control), the Raspberry Pi functions as the real-time supervisory controller: it executes the charging algorithm (control loop) implemented in ev_charger_ui.py, acquires analog measurement data via the ADS1x15 ADC over I²C (using smbus/smbus2), computes control actions (current/voltage set points, charge-phase transitions, and fault responses), and issues actuation commands through the MCP4725 DAC and GPIO (via RPi.GPIO) to the power stage

(relays/MOSFET drivers). It also provides the human-machine interface through the Kivy application, logs telemetry and events for diagnostics, and enforces safety by monitoring thresholds (overvoltage, overcurrent, and temperature) and initiating immediate shutdown sequences when limits are exceeded. In short, within this programmatic configuration the Pi is the deterministic measurement-decision-actuation platform that integrates sensor input, control output, UI, and safety interlocks to manage the charger's operation.

EV Battery Charging Topologies

Various charging topologies are used to transfer electrical energy efficiently from a source to a load.

Linear Charging Topology

This method directly connects the power source to the load through a resistor or linear regulator. Voltage regulation is achieved by controlling current flow. Although simple and inexpensive, it has low efficiency due to significant power losses and is suitable only for low-power applications.

1. Buck Converter

Reduces a higher input to a lower output voltage. Duty cycle controls the switching of the circuit. Converter offers high efficiency and accurate voltage regulation, making it widely used in battery chargers and portable electronic devices.

2. Boost Converter

Increases a low input voltage to a higher voltage output. Energy is stored in an inductor and released to the load, enabling voltage amplification. Common applications include photovoltaic systems, LED drivers, and energy storage units.

3. Buck-Boost Converter

This topology can either increase or decrease voltage depending on operating conditions. Its flexibility makes it suitable for battery charging systems, voltage regulators, and applications with varying input voltages.

4. Resonant Converter

Resonant converters use resonant circuits to achieve efficient power conversion with reduced switching losses and electromagnetic interference. They are commonly employed in high-power systems such as EV chargers and renewable energy converters.

5. Inductive or Wireless Charging

Transfers energy through electromagnetic induction between transmitter and receiver coils. It eliminates physical connectors and is widely used in consumer electronics and some EV charging applications.

6. Bidirectional Charging

Bidirectional systems allow energy flow in both directions. They support energy storage, grid interaction, and Vehicle-to-Grid (V2G) applications, enabling electric vehicles to both draw power from and supply power to the grid.

EV Battery Technology

Always battery performance is affected by vehicle range, efficiency, and overall cost. Hence efforts are focused on developing advanced battery technologies suitable for EV applications. The

main battery types used in EVs are lead-acid, nickel-based, and lithium-ion batteries.

Lead-acid batteries are inexpensive, reliable, and safe, making them suitable for certain high-power applications. However low energy density, heavy weight, and limited lifespan are some common limitations seen in the Lead-Acid batteries.

Nickel-based batteries, particularly Nickel-Metal Hydride (NiMH) batteries which have higher power capability and efficiency over 90%. Limitations include high self-discharge rates, generate heat during operation, and require additional control systems, increasing their overall cost and complexity.

Lithium-ion batteries are the most widely used energy in electric vehicles. The advantages are high energy density, low self-discharge, fast-charging capability, long cycle life, and excellent efficiency. Common lithium-ion chemistries include Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Nickel Cobalt Aluminum Oxide (NCA), and Lithium Iron Phosphate (LFP). Modern lithium-ion batteries can achieve energy densities around 200 Wh/kg and power densities up to 5000 W/kg. [17]

Table 2: Comparison of Batteries used in EV's

Sr.no	Battery Type	Energy Density Wh/Kg	Cycle life	Round trip Efficiency	Power density/Charge Speed	Cost
1	Lithium-Ion	150-250	1000-5000	85-95	High supports fast charging	Moderate
2	Lead-Acid	30-60	200-1500	270-90	Low-Moderate	Low
3	Flow Batteries	20-50	10000+	265-85	Moderate	High
4	Super Capacitors	25-10	500000	290+	Excellent	High
5	Sold State Batteries	300-500	22000-10000	290-98	Moderate High	High
6	Hydrogen Fuel Cells	30	1000-5000	40-60	Long duration storage	Very High

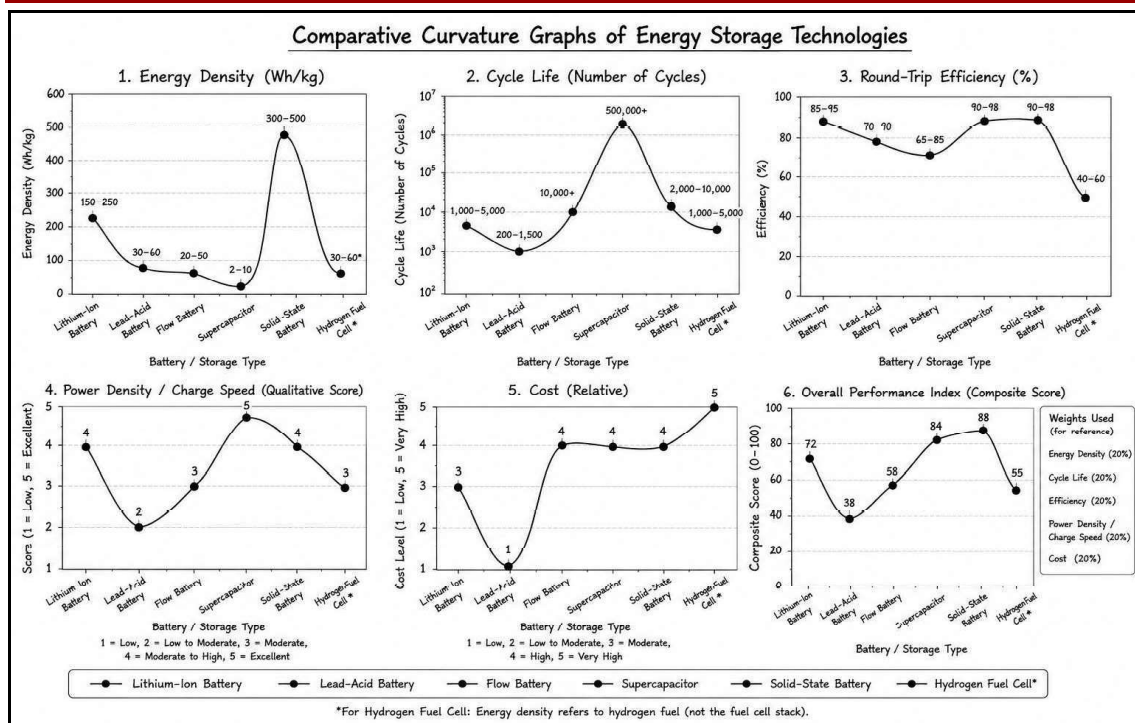


Figure 3: Comparative curvature graphs of energy storage technologies

Battery Charging Methods

1. Constant Voltage Charging (CV)

In this method, the charger maintains a fixed output voltage throughout the charging process. At the beginning, the battery draws a relatively high current, which gradually decreases as the battery approaches its fully charged state. Once fully charged, the battery can remain connected to the charger at a float voltage level to offset natural self-discharge and maintain charge.

2. Constant Current Charging (CC)

Constant current charging supplies a steady current to the battery regardless of its terminal voltage. This method is simple and inexpensive however excessive charging can generate heat and shorten

battery life. Therefore, charging should be stopped when the battery reaches full capacity. This technique is commonly applied in nickel-based batteries.

3. Constant Current–Constant Voltage Charging (CC–CV)

This method gives the combined benefits of both CV and CC methods. Charging begins with any fixed current, allowing the battery voltage to rise steadily. When a predetermined voltage threshold is reached, the charger switches to constant voltage operation. During this stage, the charging current gradually decreases until the battery is fully charged. This provides fast charging while minimizing the risk of overcharging. This method is widely adopted in lead-acid and lithium-ion batteries.

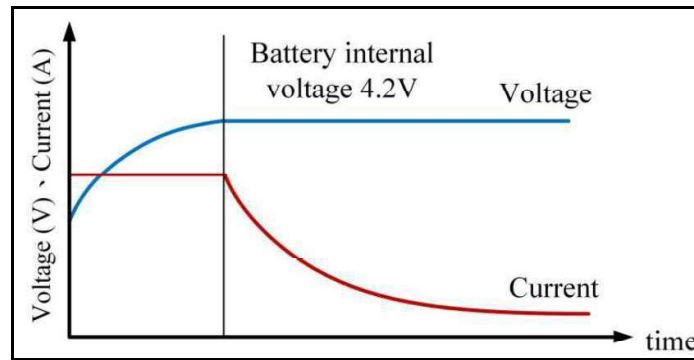


Figure 4: Constant Current–Constant Voltage Charging topology

CONCLUSION

The proposed charger is designed based on the **Constant Current–Constant Voltage (CC–CV)** charging strategy, which is widely recognized as the most effective and reliable method for charging lithium-ion batteries used in electric vehicles (EVs). Initially, the charger operates in the constant-current mode, supplying a controlled charging current until the battery voltage reaches the predefined threshold. Subsequently, it automatically switches to the constant-voltage mode, where the charging voltage is maintained at a constant level while the charging current gradually decreases until the battery is fully charged. A **Pulse Width Modulation (PWM)** signal generated by the microcontroller drives the MOSFET to regulate the charging current with high precision. Voltage and current sensors continuously monitor the battery parameters and provide real-time feedback to the microcontroller. Based on these measurements, the microcontroller dynamically adjusts the PWM duty cycle to maintain the desired CC–CV charging profile. Furthermore, the charger operates in coordination with the **Battery Management System (BMS)** to monitor battery voltage, current, temperature, and overall battery condition. This integrated control approach enhances charging efficiency, prevents overcharging and overheating, extends battery lifespan, and ensures safe, reliable, and efficient operation throughout the charging process.

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A Study On The Level Of Customer Satisfaction With The Usage Of E-Commerce Services With Reference To Pimpri-Chinchwad City

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ABSTRACT

E-commerce is a great revolution in the globalization era. The technological change has taken place in the last decade for the business. E-commerce is wide-range of business that including various types of application such as E-banking, electronically shopping, finding Job, conducting an auction etc, consume are the king of the Market, nowadays consumer is the using the internet not only for buying the goods and services but also using it for comparing price and the decision-making purpose. The research examines various factors such as product variety, convenience, time saving, low prices, 24×7 availability, availability of detailed product information, transaction security, service quality, and the growth of E-commerce usage. The business is framing the strategies to meet the demand of online shopping. Hence the objective of this research paper to focus on the satisfaction level of consumers in the field for E-Commerce World, and identifying the factors influencing the purchase of various products through online mode.

Introduction:

E-Commerce platform is one of the great opportunities available to expand the business. It is used with the help of technology, computers and the Internet for getting better performance in the market. The Industrial revolution of the Eighteenth century involved changes not only in production but also in financial structures, transport, communication and network. The Internet is one of the major changes that bring the advance technology as well as enhance the communication and networking among the business. The Internet gives a wide range for business activities. E-commerce is changing the way of buying behaviors of consumers. Many companies are changing the marketing strategy to rich the consumer. Companies are using the internet to reduced the cost therefore reducing the price of product and services to stay in the highly competitive market. We have seen that nowadays companies are also using internet for selling the product, communication and share the information, taking feedback, feedback survey, and understanding the needs of the customer etc., E-Commerce business or application began in around 1970 for innovative electronic transfer of funds. But the application was limited to large company and few brave small businesses. Since the commercialization of the internet and the introduction the web in the early 1990s, more industries are participation and process the business through electronic data interchanges (EDI). Now E-Commerce is broad. There are many applications are available the avail the services of buying goods and services such as shopping electronic malls, buying stocks, searching the Job, Banking activities, conduction auction, providing the customer services etc.,

Customer are using internet not only for buying product online but also comparing the prices, feature of the product, after sales services other facilities so on. Customer are getting more option and optimize the various services very easily. The growth of internet is providing the developing prospect for E-Commerce Market. If the E-commerce know the factors affecting the online behaviors of consumer will the better opportunities to the E-Commerce market to fulfill the consumer satisfaction level. Pimpri- Chinchwad City is one of the fasted developing city. It is fifth largest city in Maharashtra. It has developed as the third fastest growing city in the country. It having huge

industrial area which operated and providing the services all over the India. According to above discussion the main objective of this paper is to focus on consumer satisfaction level of E-Commerce Services.

Literature Review

Research by **Chanana and Goele (2012)** Studies indicate that improved digital infrastructure, rising consumer awareness, and cost-effective products have driven significant growth in India's e-commerce sector. Furthermore, the research suggests that the increasing availability of the internet and favorable demographic factors will continue to fuel the growth of retail sales in the future.

The research paper by **Zahoor and Shabir (2018)** "Future Perspectives of E-Commerce: A Conceptual Study" Research highlight that the increasing availability of the internet, advancements in digital payment technology, and the widespread use of smartphones have transformed modern business through e-commerce. Studies also highlight that while the expanding e-commerce market in India offers benefits such as market growth, reduced business costs, consumer convenience, and entrepreneurial opportunities, it also faces significant challenges—specifically regarding cybersecurity, data privacy, product quality, and intense competition. To ensure sustainable growth and future success in e-commerce, it is essential to strengthen digital infrastructure; simultaneously, making improvements to build and maintain consumer trust is equally important.

Gajewska et al. (2020) Their research paper reveals that factors such as service quality, transaction security—particularly delivery reliability—and customer satisfaction play a pivotal role in the e-commerce business. The study concludes that improving services and meeting customer expectations in a timely manner are essential for building trust and fostering long-term customer loyalty.

Akhter and Khan (2026), They identify customer satisfaction as a crucial element in e-commerce. Factors contributing to satisfaction include ease of website usage, product quality, payment security, delivery services, pricing, and customer support. The study also demonstrates a significant positive correlation between payment security and customer satisfaction; furthermore, it highlights that enhancing the quality of delivery and services can significantly improve the online shopping experience.

Objective of the study

1. To study the satisfaction level of consumer of E-Commerce in Pimpri Chinchwad City.
2. To find out the reason of satisfaction level of consumer in Pimpri Chinchwad City.
3. To understand reason for which consumer preference toward online shopping.

Research Methodology

The descriptive research design is used for the research study. The study concerned describing the characteristics of particular group of specific individuals hence this study is descriptive in nature. This study includes the primary and secondary data. The Primary data includes -The total population of the study is indefinite. The sample size of the study is 100 from the population. The convenient sampling is used for obtain the data. It is a definite plan for obtaining a sample from a given population. These techniques used for adopting the sample from the population. Secondary data collected through published Articles, Research paper, Magazines, News Paper etc.

Statistical Tools-

The research data collected through the structured questionnaire. And the data analyzed has been done with help of the simple percentage techniques and ranking analysis with MS-Excel.

Limitation of the study

- The study is only based on the consumer satisfaction of E-Commerce.
- The collected data is fully on primary data given by the respondent.
- The study has been limited to 100 respondents.
- The study is confined to Pimpri-Chinchwad City only.

Consumer - A person who buys products, goods or services for personal use but not for resale. Someone who can be influenced by the marketing and advertisement, and who can make a decision whether purchase or not the goods or services from store.

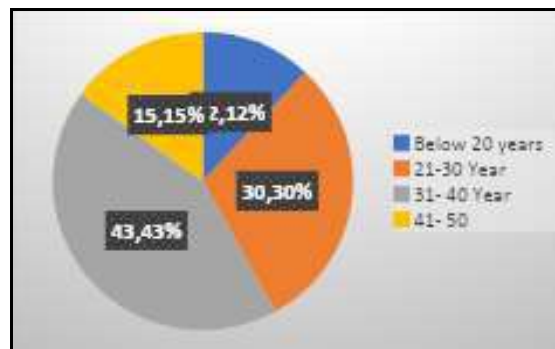
E-Commerce - E-Commerce is process that customer take decision to purchases a goods or services through internet. Consumer buy the product or services from anywhere and anytime from online store. It is one of the coinvent platform to explore the various types of goods and services, communication, providing the feedback, to compare the price etc.,.

Data Analysis

Table showing Number of Respondent - Number of Respondent who response the questionnaire - 100 (100%)

Table No.1 Table showing age wise analysis

Sr.No	Age (In Years)	Number of Respondent	Percentage
1	Below 20 years	12	12%
2	21-30 Year	30	30%
3	31- 40 Year	43	43%
4	41- 50	15	15%



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Figure No. 1 age wise analysis

Above table and chart shows that 12% respondent are from age group of below 20, and age group of

21 to 30 year are more than double i.e 30%. 43% respondent are from the age group of 31 to 40 in other hand age group of 41 to 50 are only 15%.

Table No. 2 showing Analysis by Education

Sr.No	Education Qualification	Number of Respondent	Percentage
1	Below HSC	15	15%
2	HSC	18	18%
3	UG	37	37%
4	PG	20	20%
5	Other	10	10%

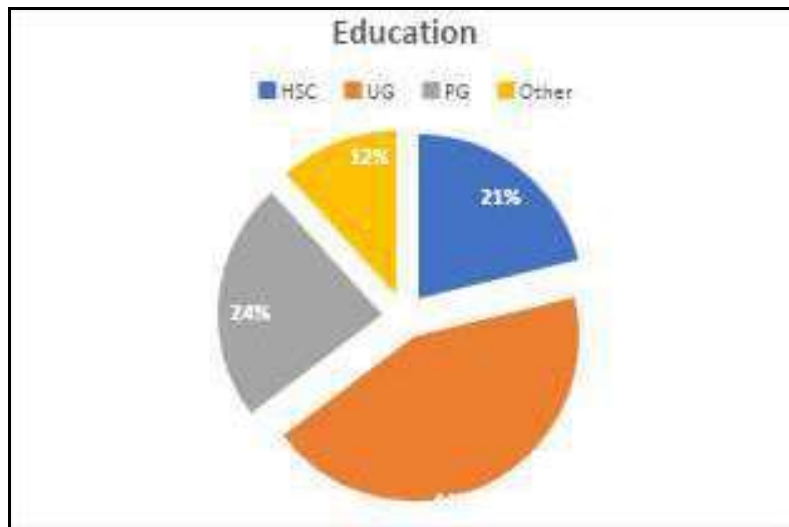


Figure No. 2 Analysis by Education

Table and chart shows that 15% respondent are not completed their HSC, whereas 18% respondent has completed their HSC. 37% respondent completed

their UG and 20% are completed their PG. only 10% respondent done their other educational qualification.

Table No 3 showing analysis by Monthly Income

Sr.No	Monthly Income (In Rs.)	Number of Respondent	Percentage
1	Below 10000	7	7%
2	10000 to 30000	22	22%
3	30000 to 50000	47	47%
4	50000 and above	24	24%



Figure No. 3 Analysis by Monthly Income

Above table and figure shows that 7% respondent having less than Rs.10000 Monthly Income, whereas 22% respondent having income between

Rs.10000 to Rs.30000. 47% respondent earning Rs. 30000 to Rs. 50000 monthly incomes. Only 24% respondent earning more than Rs. 50000.

Table No 4 Showing Statement Analysis Reading to Consumer Satisfaction Level Of E-Commerce Services

Sr. No	Statement	SA	A	N	D	SD	Total with Percentage
1	More options and choice for product in E-Commerce	74 74%	21 21%	3 3%	01 1%	01 1%	100 100%
2	There is more suitable doing activities through online	65 65%	23 23%	5 5%	3 3%	04 4%	100 100%
3	It saves the time	76 76%	21 21%	1 1%	01 1%	01 1%	100 100%
4	The main advantage of buying product online is in low price	70 70%	25 25%	3 3%	01 1%	01 1%	100 100%
5	There is impact of online on Offline	72 72%	25 25%	1 1%	01 1%	01 1%	100 100%
SA- Strongly Agree A- Agree N- Neutral D- Disagree SD- strongly Disagree							



Figure No. 4- Consumer Satisfaction Level Of E-Commerce Services

The above table shows the consumer satisfaction with help of their recondense research get to know that 74% and 21% respondent are strongly agree and agree respectively that there is more options and choice for product in E- Commerce. 7% respondent are Natural whereas only 1% respondent are disagreeing and strongly disagree. 65% and 23% of respondents, respectively, have strongly agreed or expressed agreement that e-commerce initiatives are more suitable. 5% of respondents are neutral, while 3% and 4% disagree and strongly disagree, respectively. 76% and 21% of respondents strongly agree and agree,

respectively, that e-commerce saves time; conversely, the proportion of respondents who are neutral, disagree, or strongly disagree is 1% for each category.

70% and 25% respondent are strongly agreeing and agree buying product online is in low price, in other hand 3% respondent are natural and 1% Disagree and strongly Disagree respectively. 72% and 25% respondent are Strongly Agree and Agree that there is huge impact of online over Offline. And only 1% respondent from each are Neutral, Disagree, strongly Disagree.

Sr. No	Statement	SA	A	N	D	SD	Total with Percentage
1	24 X 7 Availability	80 80%	20 20%	0 0%	0 0%	0 0%	100 100%
2	Getting detail information of product is available	65 65%	22 22%	7 7%	04 4%	02 2%	100 100%
3	It is Safe and Secure transaction	62 62%	30 30%	2 2%	01 1%	05 5%	100 100%
4	E-commerce and Internet is integral part of everyday	89 89%	11 11%	0 0%	0 0%	0 0%	100 100%
5	Service quality is satisfactory	60 60%	20 20%	4 4%	6 6%	10 10%	100 100%
6	There is growth in usage of E-Commerce transaction	88 88%	12 12%	0 0%	0 0%	0 0%	100 100%

SA- Strongly Agree	A- Agree	N- Neutral	D- Disagree	SD- strongly Disagree
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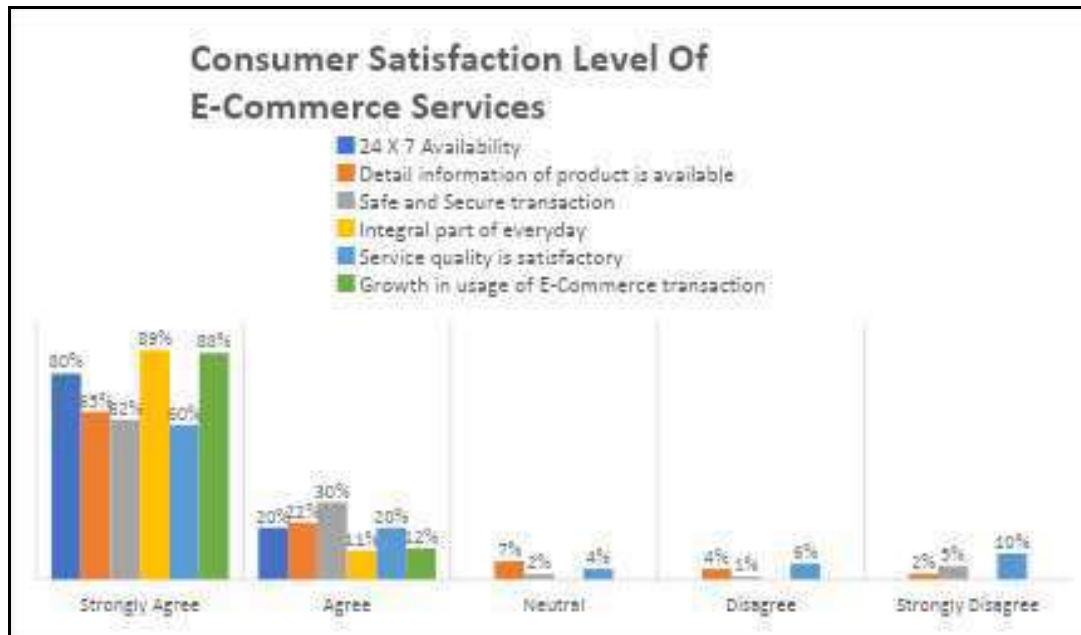


Figure No. 5- Consumer Satisfaction Level Of E-Commerce Services

Out of 100 respondents, 80% strongly agree and 20% agree that E-commerce provides 24x7 availability. No respondent expressed a negative opinion, showing complete satisfaction with continuous online access. Approximately 65% of respondents strongly agree and 22% agree that detailed product information is available online. However, 7% of respondents are neutral, 4% disagree, and 2% strongly disagree; this indicates that some users still face difficulties in obtaining complete information about the products. The data indicate that 62% of respondents firmly believe e-commerce transactions are safe and secure, while 30% agree with this view. Meanwhile, 2% of respondents are neutral, 1% disagree, and 5% strongly disagree; this suggests there is some degree of concern regarding the security of transactions. A vast majority of the survey participants consider e-commerce important in their daily lives; 89% fully agreed with this, while 11% agreed. No negative feedback was recorded in this regard. Regarding service quality, 60% of participants fully agreed and 20% agreed that the quality of service is satisfactory. However, 4% of customers are neutral, 6% disagree, and 10% strongly disagree; this indicates that some

customers are not entirely satisfied with e-commerce services. The study reveals a significant rise in e-commerce usage, as 88% of respondents strongly agree and 12% agree that e-commerce transactions are steadily increasing. No negative opinions were recorded in this regard.

Finding

- Research indicates that approximately 74% of respondents strongly agree—and another 21% simply agree—that e-commerce offers a wide range and greater variety of products; furthermore, product variety is highly value by consumers when shopping online.
- 88% of respondents (65% strongly agree and 23% agree) state that working online is more convenient and appropriate; furthermore, they show a positive response to the growth of digital platforms.
- Studies have shown that 97% of respondents fully agree that the biggest advantage of e-commerce is saving time.
- Studies show that 95% of respondents believe products are available at lower

prices through online shopping; thus, the price advantage appears to have a significant influence on online purchasing decisions.

- Approximately 97% of respondents believe that online business impacts offline business, noting the growing influence of e-commerce on traditional retail markets.
- With 24/7 service availability, 98% of respondents agree that this has a positive impact on shopping, while 20% acknowledge that there can be a negative impact as well.
- 87 respondents have firmly stated that detailed product information is readily available online, which aids in making informed purchasing decisions.
- 92 percent of respondents consider online transactions to be safe; however, a small number of people still express concerns regarding financial security.
- A key finding of the study—based on 100% of the responses—is the conviction that e-services, e-commerce, and the internet have become an integral part of daily life, driving significant changes in the digital landscape; consequently, this shift necessitates substantial implementation and development within the digital sector.
- Regarding services provided via e-commerce, a satisfactory level of service quality is evident; 80% of respondents expressed satisfaction, while 16% reported dissatisfaction or held a neutral stance—indicating scope for improvement in customer service and delivery quality.
- Feedback from all respondents reveals a high volume of e-commerce transactions, underscoring the robust expansion and extensive reach of online trade.

Conclusion

This research clearly indicates that consumers hold a highly positive view of e-commerce. Beyond the convenience and time savings, consumers identify product variety and good quality, lower prices, and 24/7 availability as key benefits. Furthermore, respondents consider e-commerce an integral and

vital part of modern life, noting a steady increase in its usage.

Research indicates that while online transactions generally appear safe and satisfactory, customers still harbor concerns regarding security and service in certain respects. These concerns pose challenges to strengthening customer trust. To bolster this trust, e-commerce companies need to focus on factors such as high-quality service and transaction security. The study reveals that e-commerce has transformed consumer purchasing habits, and this trend is likely to accelerate in the future.

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- 10) <https://pdfs.semanticscholar.org/a422/f0a2f95d04c6cf8362e599f6e89a9000a1d8.pdf>
- 11) <https://www.emerald.com/ijppm/article-abstract/69/4/666/164099/The-impact-of-the-level-of-customer-satisfaction?redirectedFrom=fulltext>



Effect Of Basic Mountaineering Course Training On Task-Specific Confidence: A Comparative Pre-Test And Post-Test Study Of Male And Female Trainees At Abvimas, Manali

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ABSTRACT

Mountaineering as exploration of a variety of adventure activities in high altitude mountains popularised across the world post first civil expedition to Mount Everest. Mountaineering training involves high-risks & still ensures safety & promotes exploring high altitude mountains. Training prepares trainees for theoretical & practical experiences. The objective of this study is to present a comparative analysis of task-specific confidence among mixed-gender trainees undergoing a rigorous Basic Mountaineering Course (BMC). Researchers studied 51 mix-respondents from ABVIMAS. "Pre-Post" primary data collected using questionnaires to analyse results to measure "growth in confidence". It is observed that training significantly improves trainees' task-specific confidence.

INTRODUCTION

Post 29th May 1953, after the first successful civil Everest Expedition by Sir Edmund Hillary & Sherpa Tenzing there was a race across the globe among the climbers to explore various mountains & peaks. In 1954, Himalayan Mountaineering Institute was set up in Darjeeling for imparting courses & training. Progressively, in 1961 Western Himalayan Mountaineering Institute (later known as Atal Bihari Vajpayee Institute of Mountaineering & Allied Sports, Manali in 2008) was founded.

Mountaineering as adventure sports became most popular among youths in India & Abroad. To facilitate training to the masses, many other institutions evolved over a period of time. Mountaineering Institutes offers a variety of adventure courses viz Basic Mountaineering Course, Advanced Mountaineering Course, Method of Instructors, Search & Rescue, Skiing, Water Sports, Aero Sports. These courses are open to male & female trainees between certain ages across the world.

RESEARCH METHODOLOGY

A study adopted a quantitative pre-test and post-test survey design. Primary data collected from Basic Mountaineering Course Batch trainees of ABVIMAS, Manali, Himachal Pradesh in the month of June 2026. Primary Data collected using google form circulated for a particular course. Out of total 114 basic mountaineering course trainees 'responses of Sample Size of 51 trainees (Male=45 & Female=6) were collected using convenience sampling method. Six-items Task-Specific Confidence Scale measured on a five-point Likert scale & results were analysed using statistical tools.

Researcher observed that very few studies available regarding mountaineering training which studies confidence level of trainees & growth in task-specific self-confidence & also gender-specific challenges or perceptions with respect to highly technical mountaineering training, considering this gap and attempt has been made to review some important study papers in journals & using primary data collected from trainee of ABVIMAS, Manali (Himachal Pradesh)

OBJECTIVES OF RESEARCH PAPER

- 1) To compare the baseline confidence level of male & female trainees before starting the Basic Mountaineering Course.
- 2) To measure the change (growth) in the tasks-specific self-confidence after completion of one week of mountaineering training.
- 3) To identify gender-specific challenges / perceptions of trainees with respect to technical mountaineering training skills.

HYPOTHESIS

H01 – There is no significant difference between pre-test & post-test confidence levels of BMC Trainees.

H02 – There is no significant difference in confidence growth between male & female trainees.

THE SELECTED LITERATURE REVIEW

The literature on mountaineering & adventure sports activities is vast & growing, reflecting its importance for the research field. In this section literature review of a few papers were carried out by researchers to understand the key scholarly contributions that have shaped understanding in this field.

1) The author's discussion is focused on gender differences in risk perceptions for mountaineering. It states that men & women perceive risks differently when introduced in mountaineering activities. Men usually show lower perception of risks when compared with women in mountaineering related activities. Men do not wish to face serious risks or possibility of accidents. While women respondents show higher risk perceptions & reported a serious risk, experiencing anxiety & distress related to mountaineering. The author also discussed that women show less frequency as compared to men who climb five times higher than women. The author underpinned that, there is need for awareness & education for men climbers to enhance safety in high-risk outdoor activities. (Novie Susanto*, 2018)

2) The author measured & compared self-confidence levels among a total 40 male and female participating in Cross-Country Mountaineering & Skiing activities from

ABVIMAS equally from the Mountaineering & Skiing category. Self-confidence level checked one-way ANOVA. Authors observed that, there is significant gender-based difference in self-confidence level. The author observed that male shows higher self-confidence than female respondent. Author suggests that sociocultural, psychological & sports specific factors contribute to differences among male & female. (Raghubanshi, (2023))

3) Author introduced concept of Self-Efficacy. It is defined as an individuals' belief in their capacity to organize, execute actions to achieve specific objectives. Theory discusses that, mastery experiences are most influential source of self-efficacy development. In mountaineering training, successful completion of challenges in handling tasks can increase confidence. Author discussed about person's belief about their abilities to successfully perform a specific task. Task specific confidence is based on author's Social Cognitive Theory. It is developed through mastery experiences, observations of others, positive emotional states etc. Higher Self-Efficacy improves resilience, motivation & performance in demanding situations which is important for success in tasks. (Bandura, 1977)

4) Author talks about Experiential Learning Theory which says learning a continuous process of experience, reflection, conceptualization, and application. Training allows trainee to learn from real life challenges & practice. Experiential learning increases technical skills, confidence, leadership, and problem-solving abilities. (Kolb, 1984).

5) The Author discusses about Outdoor Adventure Education program use physical as well as psychological challenges in natural environments to develop interpersonal connection, self-perception and personal adoptive skills. Author has highlighted that, 5 days residential outdoor adventure program produces significant growth in psychological resilience ($ES = 0.38$ 6.29%) increase, much higher than campus-based control groups. Author talks about strong group ties, independence and mastery over skills were important mechanisms pushing these adoptive

changes. Author mentioned that, important gender specific trajectories in experimental learning have been emphasized by the fact that female showed greater adoptive improvements and which were 35% more than male participants to get high positive outcome in terms of resilience. Author finds that, these results confirm that short term adventure-based treatment can effectively encourage the development of task specific competency, self-efficacy as well as ability to manage the stress. (McKenna, 1999).

6) Author(s) discussed that, historically the outdoor adventure education field has been dominated by hegemonic philosophies that emphasize risk taking, endurance and physical domination. Author used quasi experimental mixed method to measure gender based psychosocial effects throughout a 21 days Outdoor Program. Author highlighted that, there is no significant gender difference in long term retention and also life effectiveness improvements. The intervention produced substantial gender difference in post program resilience i.e. $p = 0.02$, $d = 0.56$ for Male and $d = 0.11$ for Female at Time 2). Author observed that, rigid gender binaries had for less impact on participants task adoption than individual criteria including baseline physical fitness, past outdoor experiences and individual history. (Akhurst, 2023).

7) Author discusses about the Adventure Education models systematically improve psychological outcome in physical setting. Pre & Post study of 492 students made to evaluate Adventure Education involvement planned around challenge and controlled risks. Author observed significant pre to post increase in motivation, self confidence level, enjoyment and resilience ($p < 0.001$). Author used ANOVA which revealed no significant time x gender interaction, representing that post-intervention psychological improvements arises uniformly across both male and female participants. Author highlights utility structured pre-test and post-test designs in measuring intervention driven self-efficacy and resilience across both genders. (Andrés Calmaestra-Sánchez 1, 2026).

8) Author discussed about the experiential learning

which demonstrate that short term outdoor education is effective catalyst for individual development and psychological growth. Author assessed 90 university students for one day outdoor education program perceived self-efficacy using single group pre-test and post-test (50 male and 40 female). Author studied communication focused problem-solving activities, high level challenges and experiential learning activities. Author discusses that, after the course of action, self-efficacy scores significantly increase ($p < 0.05$). Author also observed that, gender revealed no significant difference in self-efficacy increases. This data shows that structured, short term experimental outdoor activities promote self-efficacy irrespective of gender. (Yildiz, 2016).

9) Author discusses that, variety of psychological processes are responsible for viz. motivation, self-efficacy and coping techniques for success as athletics. Author investigated into how gender modifies relationship between psychological factors and sports outcomes in a comparative analysis of 60 adult athletics (30 male and 30 female). Author revealed that, compared to male athletics, female shows better psychological self-efficacy ($p < 0.05$) and intrinsic motivation to experience stimulation ($p < 0.01$). Author used regression modelling also to show that female performance was more dependent on intrinsic motivation and self-efficacy and performance of male was mostly predicted by achievement motivation and confidence. (Dhankar, 2024).

10) Author discusses that adventure education has consistently positive psychological outcome across varied participants groups. Author conducted largest analysis of field and synthesizing findings from 96 independent studies connecting more than 12000 participants. Author concluded that adventure education significantly improves self-concepts, leadership quality, interpersonal skills, personality development & academic performance. (Hattie, 1997)

11) Author discussed about gender differences in self-confidence which were examined across educational as well as physical activities background. Author described that male often displays higher confidence before performing unfamiliar tasks despite equal objective performance. Author specified that these differences are frequently attributed to socialization process rather than actual competency. (Lundeberg, 1994)

12) Author discussed in his book about educational intervention studies that commonly employ pre-test and post-test designs to measure changes attributable to the training programs. Author recommends this approach as it directly quantifies learning and psychological development while monitoring for baseline differences. In outdoor education research, pre-test and post-test assessments of participants are frequently analysed using paired samples t-tests and independent-sample t-tests to examine group improvements. Author also highlights that; such design is particularly suitable for evaluating changes in tasks-specific confidence among male and female trainees in outdoor adventure training environments. (Fraenkel, 2019)

13) Author evaluated motivational determinants of pre-service teachers towards outdoor teaching skills across Swiss Teacher Universities. Author used structural equation modelling which revealed that personal interest in nature as a learning environment as well as strong belief beliefs in outdoor teaching developmental benefit viz social, cognitive, emotional and transversal which served as the primary driver in learning motivation. Author interestingly comes across that, self-efficacy beliefs had a mixed, negligible overall effect. Whereas the global environment is concerned with only indirect influence. Author highlights that initial teacher training must nurture interest and positive outcome expectations to foster workable outdoor teaching adoption. (Smit, 2026).

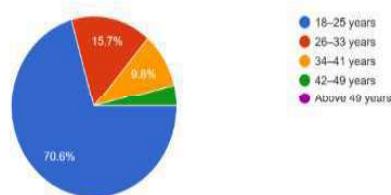
DATA ANALYSIS & INTERPRETATION

A) Demographic variables of the respondents:

i) Age in Years: (Source: Survey Data)

Sr. No.	Age Groups	No. of Respondents	Percentage (%)
1	18 to 25	36	70.59%
2	26 to 33	8	15.69%
3	34 to 41	5	9.80%
4	42 to 49	2	3.92%
	Total	51	100.00

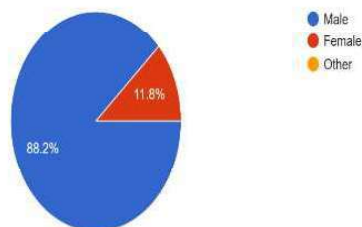
Age Group
51 responses



ii) Gender: (Source: Survey Data)

Sr. No.	Gender	No. of Respondents	Percentage (%)
1	Male	45	88.24%
2	Female	6	11.76%
	Total	51	100.00

Gender
51 responses



INTERPRETATION OF TABLES

For Age in Years: Majority (70.59%) of the respondent belongs to 18-to-25-year age group. While remaining respondent belongs to 25 years & upper age group.

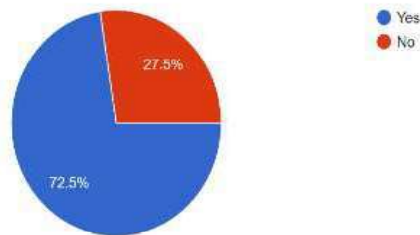
For Gender: Majority (88.24%) of the respondent are Male trainees while remaining (11.76%) of the respondent are Female trainees.

iii) Prior Exposure to Trekking/Outdoor Activities:

Sr. No.	Prior Experience	No. of Respondents	Percentage (%)
1	YES	37	72.55%
2	NO	14	27.45%
	Total	51	100.00

(Source: Survey Data)

Previous Trekking / Outdoor Experience in High Mountain?
51 responses



Majority (72.55%) of the respondent are having prior outdoor experience while remaining (27.45%) of the respondent were not having any prior outdoor/trekking experience.

B) Study of confidence level of trainees:

Researcher has studied responses of 51 mixed-gender trainees of Basic Mountaineering

Course of Batch No. 380 during the month of June 2026 at Atal Bihari Vajpayee Institute of Mountaineering & Allied Sports, Manali, Himachal Pradesh (India) through questionnaire on a Five-Point Scale starting from 1 to 5 in which 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree & 5 = Strongly Agree.

Male Respondents:

Activities	Pre-Mean	Post-Mean	% Change
Rope Knots	2.69	3.93	46.28%
Basic Rock Climbing	3.31	3.98	20.13%
High-Altitude Trek Physical Readiness	3.62	4.09	12.88%
Mixed-Gender Group Comfort	4.02	4.36	8.29%
Confidence Level Technical Climbing	2.29	2.53	10.68%
Obstacle Training Comfort	3.76	4.09	8.88%

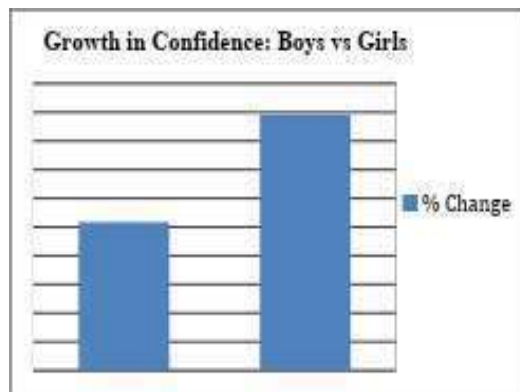
Average Growth in Confidence (%) is 17.86% (Male)

Female Respondents:

Activities	Pre-Mean	Post-Mean	% Change
Rope Knots	3.00	3.50	16.67%
Basic Rock Climbing	3.17	3.50	10.53%
High-Altitude Trek Physical Readiness	3.50	3.50	0
Mixed-Gender Group Comfort	3.50	3.67	4.76
Confidence Level Technical Climbing	1.67	2.17	30
Obstacle Training Comfort	3.50	3.50	0

Average Growth in Confidence (%) is 10.33% (Female)

GRAPHICAL PRESENTATION



C) Statistical analysis & interpretation:

i) Independent Samples t-test (Male Vs. Female): Independent Samples t-test computed on the Composite Total Growth Score (Male Vs. Female) between males and females: $t=0.9045$, $p=0.370$

Interpretation: There is no statistically significant difference in confidence growth between male and female BMC trainees ($p > 0.05$).

ii) Paired Samples t-test (Pre-Test Vs. Post Test):

Paired Samples t-test comparing pre-test and post-test confidence scores: $t=4.840$, $p=0.00001$.

Interpretation:

There is a statistically significant increase in confidence after one week of BMC training ($p < .001$).

iii) Reliability Analysis (Cronbach's Alpha):

Cronbach Alpha (Pre-Test) = 0.811; Cronbach Alpha (Post-Test) = 0.809.

Interpretation:

Both values exceed 0.80, indicating good internal consistency and reliability of the questionnaire.

CONCLUSION

The outcomes show that undertaking the Basic Mountaineering Course significantly improves trainees' task-specific confidence. The results showed no statistically significant gender-based difference in the amount of confidence gain, even though both male and female trainees demonstrated growth. The survey instrument has high internal consistency, according to reliability analysis. Therefore, regardless of a trainee's gender, the BMC training program may be regarded as helpful in fostering confidence and readiness. It has been observed that, mixed-group comfort increases for both, which indicates that Basic Mountaineering Course is succeeding in social integration during training.

LIMITATION OF STUDY

- 1) Current research is based on sample size of 51 respondents (Male = 45 and Female = 6).
- 2) This research paper is only focused on ABVIMAS, Manali (HP) mountaineering institutes.

- 3) This paper is based on Self-Reported Questionnaire & meant for Short-Term Assessment only.

FUTURE RESEARCH

Future research may include:

- 1) Multiple mountaineering institutes in India
- 2) Observe leadership skills of trainees
- 3) Study resilience & risk perception of trainees independently.

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Temperature Trend Analysis For All The State Of India Between (2000-2019)

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ABSTRACT

Temperature across India varies widely by region. Generally, the average temperature across India ranges from 24°C to 27°C annually. Summers (March to June) can see temperatures soaring from 30°C to 45°C in many regions, while winters (December to February) can range from 5°C to 25°C. Here we use Machine learning (ML) techniques for time series prediction. By using the time series prediction it becomes accurate and helpful. Here weather forecasting, climate prediction and accurate temperature prediction is important. We have studied 20 years of data sets for the year 2000-2019. The statistical analysis here collected the secondary data from the Government website.

1 INTRODUCTION:

Temperature data is crucial for understanding various environmental, industrial, and societal phenomena. Weather forecasting, climate research, agriculture, and energy management are just a few of the scientific, industrial, and societal pursuits that depend critically on temperature prediction. Making wise decisions.[1-2]

Regression is a statistical method used to examine the relationship between one dependent variable and one or more independent variables. It's commonly used for prediction & forecasting. In

simple terms, regression analysis helps to understand how the value of a dependent variable changes over time. Linear regression is the regression in which we study the relationship between dependent & independent variables. In a given data temperature is the dependent variable, by using this method we can predict short-term and long-term temperature.[3-5]

This research paper shows how to improve temperature forecast by using machine learning. Linear regression, as a classical algorithm in statistics, is widely used in various data analysis

tasks because of its simplicity and explanatory power [6-8] Additionally, this research supports continuing initiatives to use cutting- edge technology to address the urgent problems brought on by climate change and extreme weather.

The Mann-Kendall (MK) trend test is a non-parametric statistical method used to identify monotonic upward or downward trends in time series data. It is highly valued in fields like hydrology, climate science, and environmental studies because it doesn't require data to be normally distributed or linear, and it resists extreme outliers. [9-11]

Objective of Study

1. The objective of this project is to create and assess temperature prediction models using Linear Regression (LR)
2. To find trend by using scatter plot
3. To analysis change of temperature season wise by using simple bar diagram
4. To check trend analysis by using the Mannkendall test.

TABLE 1. DATA OF MONTHLY, SEASONAL ANNUAL MEAN TEMPERATURE (2000-2019)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2000	18.87	19.78	23.22	27.27	28.92	28.02	27.34	26.98	26.53	25.58	22.75	19.66	24.6
2001	18.5	21	24.12	26.9	29.46	28.13	27.63	27.62	26.86	25.49	22.51	19.55	24.73
2002	18.78	20.52	24.44	27.66	29.56	28.77	28.47	27.27	26.43	25.44	23.17	19.87	25
2003	18.6	21.03	23.62	27.29	28.64	29.01	27.53	27.25	26.75	24.92	22.17	19.59	24.72
2004	18.83	21.03	26.19	27.38	28.12	27.94	27.44	27.16	26.8	24.34	22.43	19.93	24.74
2005	19.07	20.51	24.14	26.62	28.22	28.99	27.34	27.41	26.82	24.84	21.73	19.23	24.58
2006	19.96	23.02	23.91	26.83	28.82	28.13	27.92	27.15	26.42	25.41	22.59	19.99	25.06
2007	19.24	20.97	23.52	27.72	28.84	28.31	27.66	27.37	26.61	24.92	22.4	19.65	24.77
2008	18.49	19.83	24.43	26.54	28.42	28.1	27.5	27	26.44	25.47	22.51	20.62	24.61
2009	19.79	21.66	24.55	27.35	28.71	28.77	27.83	27.85	27.11	25.2	22.31	20.22	25.11
2010	19.15	21.23	26.53	28.4	29.19	28.51	27.55	27.33	26.6	25.58	22.98	19.22	25.13
2011	18.32	20.79	24.11	26.1	28.92	28.6	27.6	27.2	26.7	25.51	22.84	19.84	24.67
2012	18.25	20.43	23.98	26.89	28.72	28.91	27.98	27.31	26.65	24.85	22.26	19.91	24.69
2013	18.88	21.07	24.53	26.97	29.06	28.24	27.5	27.22	26.87	25.63	22.18	19.69	24.82
2014	18.81	20.35	23.34	26.91	28.45	29.42	28.07	27.42	26.61	25.38	22.53	19.5	24.73
2015	19.02	21.23	23.52	26.52	28.82	28.15	28.03	27.64	27.04	25.82	22.95	20.21	24.91
2016	20.92	23.58	26.61	29.56	30.41	29.7	28.18	28.17	27.72	26.81	23.9	21.89	26.45
2017	20.59	23.08	25.58	29.17	30.47	29.44	28.31	28.12	28.11	27.24	23.92	21.47	26.29
2018	19.9	22.58	26.01	28.48	29.99	29.58	28.19	27.73	27.63	26.42	23.84	20.41	25.9
2019	19.62	21.8	24.92	28.82	30.27	30.26	28.65	27.92	27.56	26.22	23.93	20.32	25.86

METHODOLOGY

Single Model ML Methods:

Linear Regression Analysis: Linear regression analysis is used to predict the value of a dependent

variable based on the value of an independent variable. The variable you want to predict is called the dependent variable. The variable you are using to predict the other variable's value is called the

independent variable. Linear regression fits a straight line that minimizes the discrepancies between predicted and actual output values. Linear regression calculators use a “least squares” method to discover the best-fit line.

Here the linear regression equation is $y = mx + c$

Here,

m is slope of equation is intercept, y is dependent variable and x is independent variable. Linear regression analysis is used to predict the value of a variable based on the value of another variable.

Descriptive statistics:

Descriptive statistics in research are used to summarize, organize, and describe the main features of a dataset. Descriptive statistics are the summary of the given data. In measures of central tendency we study mean, mode and median, In measures of dispersion, we study variability of the given data, we visualize the data by using diagrammatic as well as graphical representation

Scatter diagram:

A scatter diagram is a graph that displays the relationship between two variables by plotting pairs

of data as points on a two-dimensional plane, with one variable on the X-axis and the other on the Y-axis.

Inferential Statistics:

Mann - Kendall Test:

The Mann-Kendall (MK) trend test is a non-parametric statistical method used to identify monotonic upward or downward trends in time series data. It is highly valued in fields like hydrology, climate science, and environmental studies because it doesn't require data to be normally distributed or linear, and it resists extreme outliers

The study concludes that Mann-Kendall statistical tests in TREND are relatively easy to understand and users can gain a good implementation of the tests by following the descriptions and the examples presented in the study. Trend analysis based on Mann Kendall statistics helps to understand how the underlying function has performed and predict where the current state of the selected function will guide the dataset .

II. RESULT AND ANALYSIS

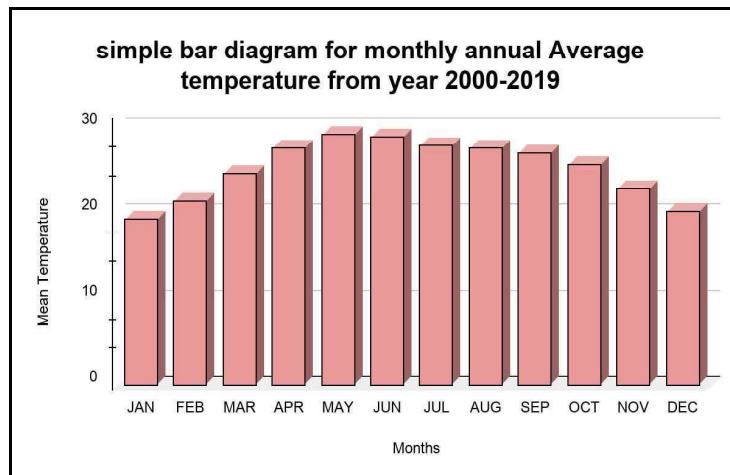


Fig1. Graphical representations of annual temperature of all india monthly for years 2000-2019

Winter temperatures typically involve a decrease in both maximum and minimum temperatures, with variations depending on location and proximity to bodies of water or mountains. The coldest months are generally December and January. The above

graph shows the lowest temperature in the months of December & January. Summer months are typically characterized by high temperatures and increased daylight hours; the above graph shows high temperatures in May. The rainy season in

India, also known as the monsoon season, typically lasts from June to September. During this period,

the southwest monsoon brings heavy rainfall to most of the country, with the heaviest rainfall occurring in July and August.

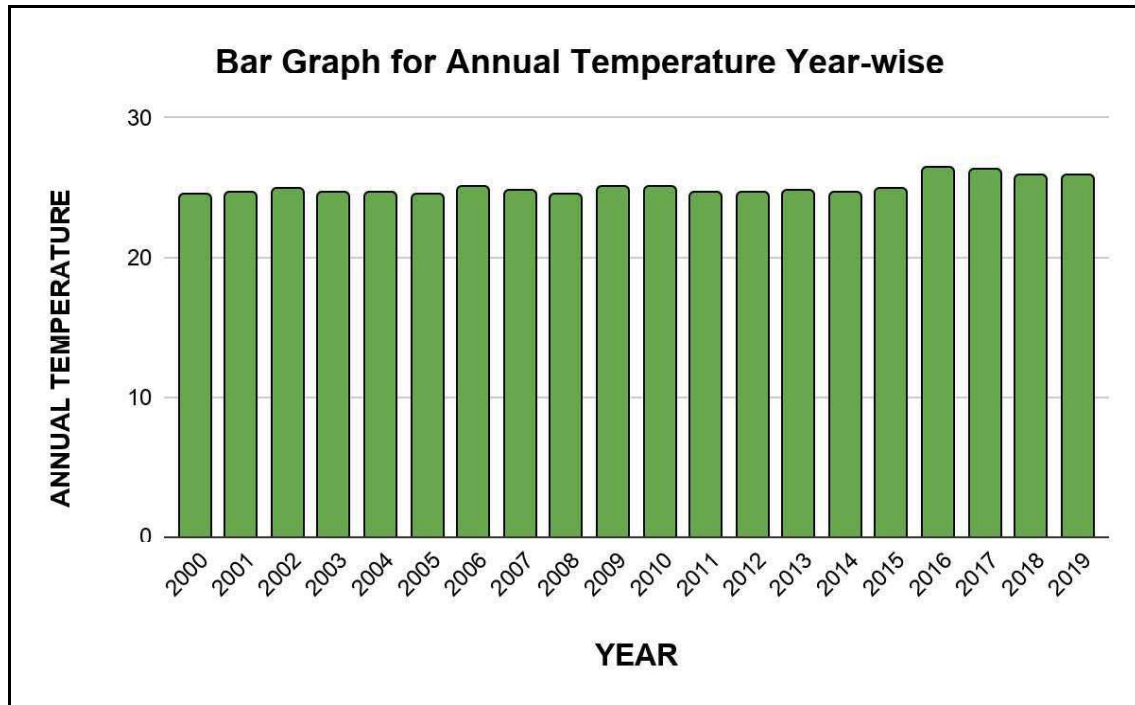


Fig 2. Annual Temperature of India for the year 2000- 2019

The temperature remains fairly stable between 24°C and 26°C throughout the 20-year period. There are small year-to-year fluctuations. From around 2016 onwards, the temperatures are slightly higher than in the earlier years. The highest temperatures are observed around 2016–2017. Overall, the graph indicates a slight

increasing trend in annual temperature, suggesting gradual warming over the years. The annual temperature of India remained mostly consistent from 2000 to 2019, but there is a small rise in temperature in the later years, indicating a gradual increase in average temperature over time.

Linear Regression By using Python:

Linear regression uses the relationship between the data-points to draw a straight line through all them. This line can be used to predict future values.

```
import pandas as pd
df = pd.read_csv('C:/Users/Admin/Desktop/data_for_lr.csv')
print(df.to_string())
  X    Y
0 2000 24.60
1 2001 24.73
2 2002 25.00
3 2003 24.72
4 2004 24.74
5 2005 24.58
6 2006 25.06
7 2007 24.77
8 2008 24.61
9 2009 25.11
10 2010 25.13
11 2011 24.67
12 2012 24.69
13 2013 24.82
14 2014 24.73
15 2015 24.91
16 2016 26.45
17 2017 26.29
18 2018 25.90
19 2019 25.86

import matplotlib.pyplot as plt
from scipy import stats
x = [2000,2001,2002,2003,2004,2005,2006,2007,2008,2009,2010,2011,2012,2013,2014,2015,2016,2017,2018,2019]
y = [24.60,24.73,25.00,24.72,24.74,24.58,25.06,24.77,24.61,25.11,25.13,24.67,24.69,24.82,24.73,24.91,26.45,26.29,25.90, 25.86]
slope, intercept, r, p, std_err = stats.linregress(x, y)

def myfunc(x):
    return slope * x + intercept

mymodel = list(map(myfunc, x))
plt.scatter(x, y)
plt.plot(x, mymodel)
plt.show()
```

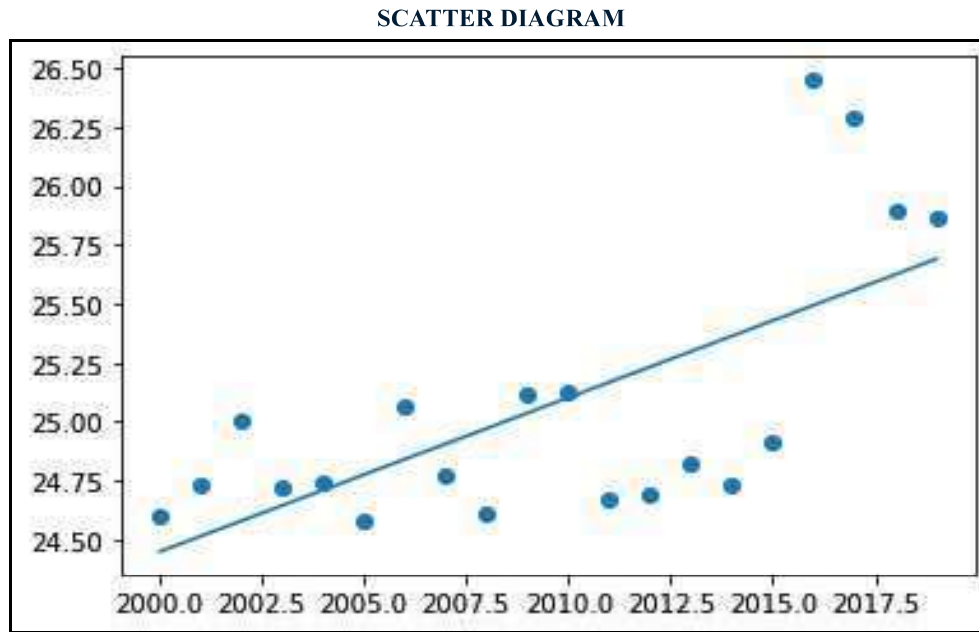



Fig 3. Scatter Plot with a fitted trend line (regression line) for annual temperature year 2000-2019

The above image shows a fitted trend line. Here we study 20 years of data for temperature. Here on X-axis(Horizontal) Years ranging from 2000 to 2019, On Y-axis(Vertical) some measured annual temperature of India year wise. The data points i.e. blue dot shows data points scattered over time with some change year by year but not perfectly linearly. Here we conclude that The trend line shows a

moderate upward trend, suggesting an overall rise in values over the two-decade period.

Mannkendall test by using python programming:

The Mann-Kendall Trend Test is a non-parametric statistical test used to determine whether a time series has a monotonic upward or downward trend

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import pymannkendall as mk
data=[24.6,24.73,25.0,24.72,24.58,25.06,24.77,24.61,25.11,25.13,24.67,24.69,24.82,24.82,24.73,24.91,26.45,26.29,
25.9,25.86]
mk.original_test(data)
```

Output of the given data:

```
Mann_Kendall_Test(trend='increasing', h=True, p=0.007023780103332822, z=2.6957146802157683,
Tau=0.4421052631578947, s=84.0, var_s=948.0, slope=0.036250000000000115, intercept=24.475625)
```

Output Interpretation:

The output interpretation can be done in the following different ways:

Trend indicates that is increasing, decreasing or no trend present here, If h is True then trend is present. If h is False then no trend is present. Here p shows the p-value of the test. Z is The normalized test statistic. Tau is Kendall Tau, s is the Mann-Kendal's score, var_s is Variance of S which shows variation between the data. Slope is Theil-Sen Estimator/slope & Intercept of Kendall-Theil Robust Line

Since in the above example, the p-value is 0.007 which is less than the threshold (0.5) which is the alpha(0.5) then we fail not to reject the accepted hypothesis i.e. we do have sufficient evidence to say that sample has a trend present. Then we reject the accepted hypothesis and it is also increasing. Theil-Sen estimator (slope) is positive; it indicates an increasing trend in temperature over time.

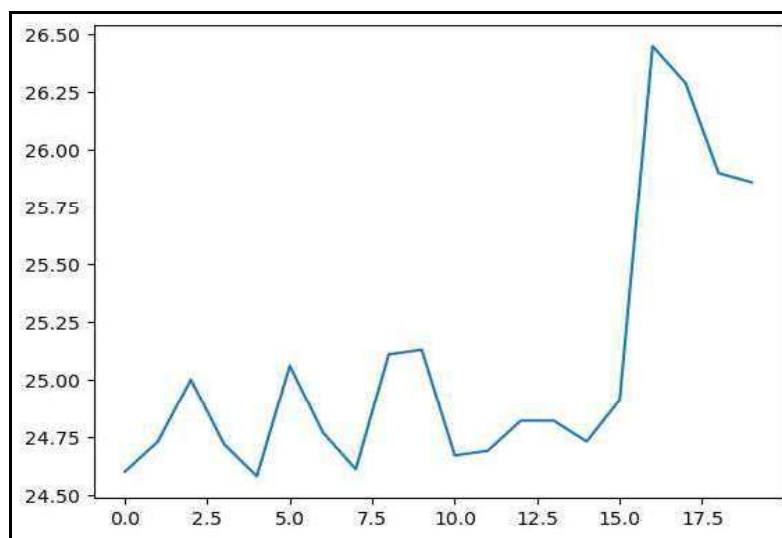


Fig 4. Visualizing the trend of the data

The temperature data for India moderate fluctuations during the initial period, the above graph shows values ranging between 24.6°C and 25.1°C. Here the above graph shows maximum temperature at the end of the period. This graph generally shows an increasing trend.

CONCLUSION

Here we conclude for overall study, lowest temperature in the month of December & January due to winter season, there are the lowest temperatures, also we conclude that the highest temperature in the month of May due to the summer monsoon. Heaviest rainfall occurs in the months of July & August. From around 2016 onwards, the temperatures are slightly higher than

in the earlier years. The highest temperatures are observed around 2016–2017. Overall, the graph indicates a slight increasing trend in annual temperature, suggesting gradual warming over the years. The annual temperature of India remained mostly consistent from 2000 to 2019, but there is a small rise in temperature in the later years, indicating a gradual increase in average temperature over time. Also we conclude that every three years the temperature increases.

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A study of significant applications of Geographical Information System (GIS) in sustainable development in India

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ABSTRACT

This paper studies the application of the Geographical Information System (GIS) in sustainable development in India. The GIS is the tool which provides digital data of geographical information for the user to analyse and make decisions. The GIS is widely useful in various fields such as precision agriculture, industry management, health sector, public transports, smart city management, infrastructure and development management, research, strategic planning and governance. GIS is very useful in digitization for observation, analysis and decision making for sustainable development of India.

Introduction:

In the current scenario every sector is accommodated with new technologies. The technologies are for observation, analysis, decision making, planning and development. The sectors like precision agriculture, health, transport, domestic services, disaster management, rural development, urban planning and smart cities, environment and climate change, water resource

management, natural resource management, defence and national security, telecommunication, business and market analysis, mining and geology, marine and coastal management and many more taken advantage of recent technologies in their growth. The Geographical Information System (GIS) is one of the tools that can facilitate the ease in handling the activities like capturing, storing, processing, analysing and displaying the

geographical data. The GIS uses geographical referenced data integrate it digitally and provides a decision making platform for real world activities. GIS has four major components: Hardware, Software, Data and Users. The Hardware embedded with Computers, Servers and Global Positioning System (GPS). Software like QGIS or ArcGIS is used to process geographical data, that data is the representation of geometry and its description. Spatial and attributes are used by the user for analysis and interpretation. In GIS the user handles the spatial information for analysis and interpretations.

Review on Applications of GIS

Geographic Information System (GIS) can effectively be used in various fields including Natural resources and Environment survey, mobility and urban planning, strategic and Scientific, Economic and Industrial and governance and public services sectors.

A) Agricultural Applications:

Agriculture not only provides food to the human being but also it provides raw material, employment and also it impacts the global economy. However, growing population, environmental crisis, water scarcity, pollution and soil degradation are the challenges to sustain agricultural fields. To overcome these challenges, promising technologies must be adopted in the agricultural field. To meet the need of all this, GIS is a promising tool for the agriculture field. It can significantly be used for collecting agricultural data for further storage, analysis and decision making approach. The crop management, soil assessment, planning of irrigation, wild and pest control can be made easy with the GIS technology. Embedding GIS technology with Artificial Intelligence (AI), Remote Sensing (RS), and Global Positioning System (GPS) made agricultural activities more precise, handy, reduced cost, increases in productivity and sustainable. Precision agriculture is incorporated with Soil management, monitoring of crop growth, irrigation management, diseases monitoring, pest control, monitoring of climate and mapping of agricultural resources [1-3].



B) Infrastructure and Development Applications:

The Geographic Information System (GIS) tool opens significant opportunities in infrastructure development and planning of urban areas. The activities like transportation management, communication network development and smart city implementation benefits by GIS technology. GIS provides spatial and non spatial information to the planners to make precise decisions in systematic development and management of urban areas.

a) Urban Planning:

Nowadays most of the people migrate towards urban cities in search of their livelihoods. This results in an increase of population density in urban areas. The demand for infrastructure and utilities is also increasing in proportion. The growing urbanization faces significant issues in management of land use, planning of infrastructure, public services, transportation, etc. The traditional methods of urban planning are insufficient to handle complex and dynamic needs of modern cities. So emerging techniques such as GIS are very helpful in urban planning.

The major components of urban planning are Land use, Land cover, Site selection, Disaster and risk management. The GIS tool significantly helps planners to prepare the maps of used land. It prepares zones of the land such as residential, agricultural, industrial and institutional. This will be further useful for monitoring the expansion of urban areas, prevention of unauthorised infrastructure development and analysis of land suitability for use. GIS also helps in population mapping, demographic analysis, and study of migration. Disaster management is one of the vital applications of GIS. The mapping of flood prone areas, earthquake sensitive regions and

accident-prone spots effectively carried out GIS [4-6].

b) Transportation:

The GIS is useful in transportation management by integrating spatial and attribute data. Planning of route network, identification of traffic pronezone, identification of accidental hotspots, passenger demand forecasting, selection for suitable location for development of transportation infrastructure can significantly improve decision making ability of planners. It also provides information to the user such as shortest route for travel, real time traffic, cost effectiveness and travel time etc.[7-8].

c) Smart city:

Digital technology is the measure component of a smart city. Sensor based automated decision making systems are used to enhance services, resource availability and sustainability. The infrastructure in smart cities such as the water supply network, Sewage system, electricity, gas pipelines, pollution monitoring and telecommunication networks can be managed by GIS technology [9-10].



C) Strategic and Scientific applications:

GIS has wide applications in strategic and scientific management. GIS collects, analyses and manages the spatial data and provides assistance to various fields such as research, defence, marine, archaeology, environment monitoring, and disaster management.

The GIS is a very useful tool in environmental research such as climate change assessment, forest cover monitoring, biodiversity conservation, pollution mapping and watershed management.



It is also beneficial in public health research in disease outbreak mapping, healthcare accessibility analysis, and epidemiological modelling etc.

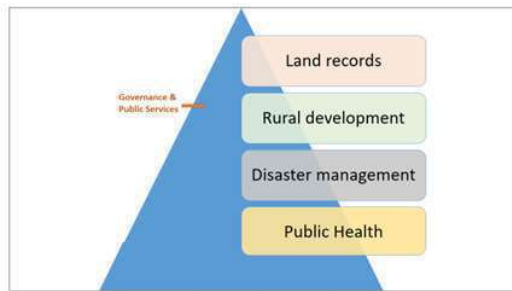
In defence it can be used for battlefield management, border surveillance, intelligence gathering .

The GIS supports ocean and coastal resource management. The coastal zone management, marine biodiversity, fisheries management, oceanographic studies and marine pollution monitoring can be facilitated with GIS [11-12].

D) Governance and Public Services applications:

In the government sector there are many location based activities such as land administration, infrastructure planning, disaster management, taxation, environmental conservation, healthcare accessibility and public utilities. Traditional methods used to handle such activities are critical and time consuming. The GIS tools provide significant applications in governance and public services. The land record can be easily digitised in GIS, it avoids traditional paper maps. The accurate boundary mapping, faster mutation, online verification is possible and it can reduce land disputes issues. It is also helpful in online verifying land ownership, land use, tax information and encumbrance records. The watershed development, agricultural planning, village resource mapping, and road planning can also easily be managed by GIS.

The disaster such as flood, earthquake, cyclone, forest fire, and landsliding can be emergency responded and managed by the use of GIS [13-14].



E) Economic and Industrial applications:

In the digital transformation era industries are using GIS tools widely to optimise operations, improve decision makings, reduction of cost and increasing sustainability. GIS also supports business intelligence, supply chain management, logistics, site identification and selection, management of energy infrastructure, market analysis and economical plannings. Economic development relies on geography of resources, population density, availability of infrastructure, markets and industries. The GIS helps policymakers in regional economic planning, identification of investment zones, industrial corridor management, planning of infrastructure, employment analysis, mapping of tourism economy and export import management etc.

In business analytics GIS supports market analysis, customer segmentation, sales territory management, supply chain management [15-16].



Discussion & Conclusion:

The Geographic Information System (GIS) is the emerging technology that supports achieving sustainable development across every sector of India right from agricultural and water resource management to urban planning, industries, health, transportation, energy, environmental conservation, business analytics, strategic management and governance. By adding satellite imagery, remote sensing data, Geographical Positioning System

(GPS), and real time geospatial data, GIS provides help to policymakers, researchers, industries, and public administrators in resource utilization, reduction of cost and enhanced operational efficiency.

Considering the current scenario of India as national initiatives such as Digital India, Smart Cities Projects, PM Gati Shakti abhiyan, National Geospatial Policy and various research institutions like ISRO supported geospatial programs have significantly increased the adoption of GIS. These initiatives in India signifies the role of geospatial technologies in overall growth, infrastructure development, climate resilience, environmental protection, and transparent governance.

Furthermore, GIS proves its role in achieving the United Nations Sustainable Development Goals (SDGs) by supporting informed planning, monitoring development indicators, conserving natural resources, and promoting equitable access to essential services. The emerging technologies such as Artificial Intelligence, Internet of Things (IoT), Drone Technology, Big data and Cloud computing continue to integrate with GIS, and will expand the role of GIS as a predictive analytics and intelligent decision support system.

In conclusion the GIS is not only the mapping tool but a strategic decision support platform in sustainable economic, social, and environmental development. The continuous investment in geospatial infrastructure, skilled human resources, and research and innovation will ensure that GIS remains a cornerstone of India's journey towards sustainable and inclusive development.

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NEP 2020: Evaluation of Faculty Preparedness and Pedagogical Barriers in Higher Education Institutions with reference to Pune city

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ABSTRACT

National Education Policy (NEP) 2020 aims to reform the higher education landscape by providing comprehensive development facilities with flexible and practical learning structures. However, several challenges exist in terms of faculty preparedness and implementing pedagogical methods. Without a rigorous approach for faculty teaching development, the policy's goals may remain unattainable. The present research paper includes both Primary data and secondary data. The primary data is collected through structured questionnaires from various colleges in Pune city and is evaluated and discussed faculty preparedness and the challenges they face in implementing the policy.

1. INTRODUCTION:

The introduction of the National Education Policy (NEP) 2020 was driven by a core vision to transform India into a global knowledge hub. The policy brought a major restructuring of the Indian

educational system from primary to higher levels to make it a more accessible and flexible learning experience for students. Focusing on the higher education landscape, the NEP 2020 aims to promote multidisciplinary learning by blurring the boundaries of Science, Commerce or Arts with

Dr. Rajkumari Tamphasana, 'NEP 2020: Evaluation of Faculty Preparedness and Pedagogical Barriers in Higher Education Institutions with reference to Pune city'

flexible facilities, such as multiple entry and exit options for students. Not only that, the policy also focuses on technology integration in teaching, learning, and assessment. Most importantly, it emphasizes providing training to teaching faculty and delivering support for continuous professional development.

As more states are increasingly implementing the NEP 2020, one significant question that draws immediate attention is the level of readiness of faculty members and their implementation of new teaching approaches. Faculty members are among the major stakeholders to make the policy successful. Besides technological integration in teaching methods, pedagogical innovation and rigorous training for faculty are key areas to focus on.

Against this backdrop of the new educational policy and its innovative approaches to teaching methods, this study aims to assess the level of faculty preparedness and identify key pedagogical barriers, if any, to implementing the NEP 2020 within higher education institutions in India.

2. OBJECTIVES OF THE STUDY:

1. To understand the concept of NEP 2020 and its reforms related to higher education.
2. To assess faculty awareness and preparedness.
3. To identify key pedagogical barriers faced in implementation.

3. REVIEW OF LITERATURE:

The Union Cabinet of India started the NEP, 2020, on 29th July 2020, to outline the vision of India's new education system. Access, Equity, Quality, Affordability and Accountability are the five guiding pillars of NEP 2020. NEP 2020 has features of holistic development, multidisciplinary learning which allow the students to explore knowledge beyond their field. Its policy provides flexibility in curriculum design through implementation of Choice-based credit system, multiple entry-exit option, integration of vocational education and skills development-based learning.

Sawant Veena (2024) explains the importance of capacity building to make the NEP 2020 a successful implementation. By highlighting a core objective to focus on improving the employability level or vocational skills of students after completing their graduation, Sawant points out that student employability leads to national development. The author further emphasizes that capacity building should work on individual, institutional and societal levels. These three levels are interconnected in a way that they support one another, contributing to the overall development and positive learning outcomes for students, ultimately benefiting society as a whole.

Aggarwal Anchal's research paper titled ^[1]“Teacher Preparedness in the Era of NEP 2020: Challenges, Understanding, and the Role of Training” examines the overall awareness of teaching faculty about NEP 2020 and the problems they encounter during implementation. The author highlights a major problem for the teaching faculty: the existing gap between their policy knowledge and level of readiness for implementation. This is a key challenge that can restrict the positive outcome of the policy. As a suggested solution, Anchal emphasizes that professional development training sessions and systematic support for teachers in multidisciplinary learning are crucial to enhancing their teaching and learning processes.

4. RESEARCH METHODOLOGY:

For the purpose of the study, the researcher used both primary data and secondary data. The secondary data was collected from related articles, research papers, websites, etc. and the primary data was collected from 50 faculty members, through structured questionnaires, from various colleges in Pune city. The questionnaires were based on their awareness and understanding of NEP 2020, their confidence level and barriers facing in its implementation.

5. FINDING AND DISCUSSION:

5.1: Awareness and Understanding:

This section examines the awareness level of NEP 2020 among faculty members after the training.

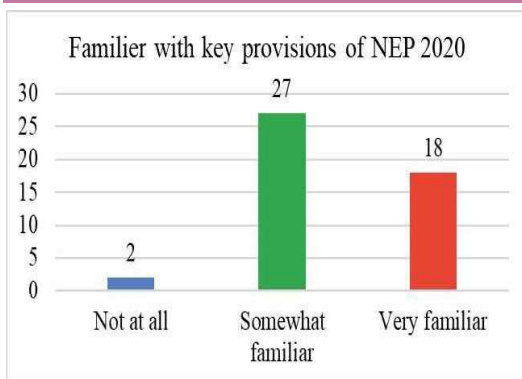


Fig. 1: Familiar with the key provisions of NEP 2020

Most faculty members are familiar and have a strong understanding of the key concepts of the NEP 2020. This means the majority of teaching faculty are aware of the primary vision and goals of the policy, aiming for the higher education landscape in India.



Fig. 2: NEP-related Workshop/ Training session

Asking about whether they have attended any training sessions related to the new policy, 80% of the faculty members attended a training session or workshop.

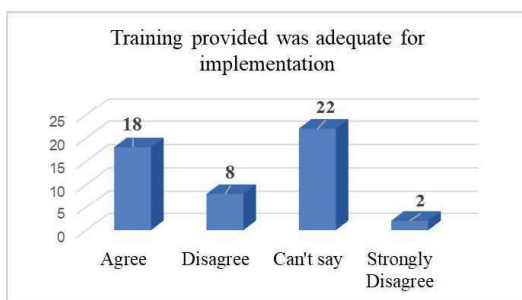


Fig. 3: Adequate for implementation with existing training

Responding to a question of whether the training was sufficient for successful implementation in the classroom, 44% of the respondents disagree. This indicates that, although they have a good conceptual understanding of the policy and attended the training, nearly half of the faculty members really can't say positively about the actual implementation.

5.2: Pedagogical Barriers in Implementation

This section examines the existing barriers that faculty staff face when implementing teaching methods that align with the new policy.

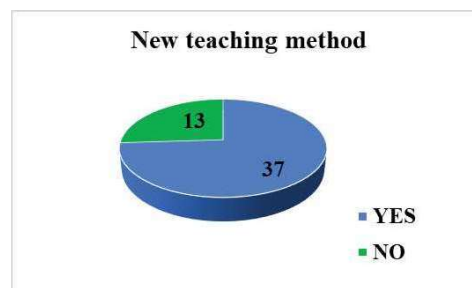


Fig. 4: Implementation of new teaching methods

More than 70% of the faculty members have started experimenting with new teaching methods using an experiential, project-based and interdisciplinary approach in line with the NEP 2020 guidelines. It shows positive responses from the faculty in adapting to new teaching approaches and technological use.

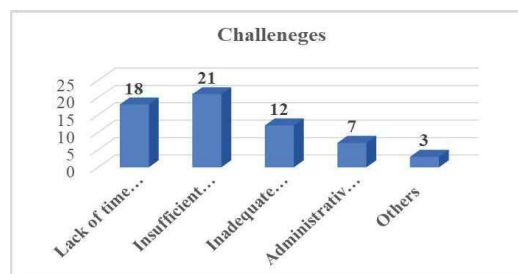


Fig. 5: Challenges/ barriers in implementation

Despite their major efforts to implement the new policy effectively, faculty members still face challenges. Over 40% of the teachers find the training provided to them to be insufficient. More than 35% of them point out that the limited time for

preparation is a major challenge, along with insufficient training.

5.3: Evaluating Faculty Preparedness

Table 1: Confidence level of NEP-aligned teaching practices

Scale (1 being not confident and 5 being highly confident)	No. of respondents
1	2
2	7
3	22
4	17
5	2
Total	50

Table 1 above shows the ratings of 1 to 5 given by the participants about their confidence level in the successful implementation of the policy. A majority, 31 out of 50 teachers, remain doubtful, despite 38% of them having a strong confidence in effectively implementing the policy.



Fig. 6: Need for more NEP-related training sessions

In answering the question of whether they are willing to attend more NEP-related workshops if offered, more than 60% of the faculty say that they will definitely join the training workshops. This highlights the desire of faculty members to learn more from training so that they are able to develop the right teaching approach that syncs with the new education policy.

6. Conclusion

Faculty members are one of the primary stakeholders for the successful implementation of the NEP 2020 since their teaching approaches and methods directly impact students' learning processes. Although several initiatives have been implemented, teaching faculty require more rigorous training and programs to boost their capacity and confidence. The availability of the right technology and comprehensive training programs can help faculty staff prepare for the massive undertaking and goals that the policy aims to achieve.

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10. <https://mail.google.com/mail/u/0/#inbox/QgrcJHsBvFcspzjmLrntDJDNRthcMWnSqHg?projector=1&messagePartId=0.6>

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