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अनुसन्धक



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St. Xavier's College Jaipur

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Aligning AI with Sustainable Climate Change

Ms. Anisa Nadar and Ms. Shraddha Kota

B. Ed. Students Batch 2024-2026

St. Xavier's Institute of Education

University of Mumbai

Abstract

Climate Change and uncontrolled AI (Artificial Intelligence) are two possible adversities that the world faces today. The possible solution to facing these environmental challenges is the sustainable advancement of artificial intelligence systems. To reach the sustainable development goal of climate action, one needs to rely on AI-led predictive climate modelling along with optimised renewable energy systems and enhanced disaster management. These issues could be addressed with SDG 13 at the forefront. This research examines the intersection between extreme weather phenomena, rising sea levels, biodiversity loss, food insecurity, and the multitude of challenges posed by climate change and the remarkable potential of AI for impact mitigation. The following research endeavours to understand the opinions of student-teachers about how AI-propelled innovations and progressive climate action can be balanced. A survey of 109 B.Ed. Students in Mumbai found that 63.3% make use of artificial intelligence every day. Almost 90% of respondents opined that rising global sea levels, air contamination, biodiversity loss, and food scarcity as the top issues triggered by climate change. 63.3% of the respondents interviewed stated that public information and education can help to initiate climate change actions in their communities. The responses showed that personal efforts like reducing energy use, aiding renewable energy sources, and doing community education are very important for climate change mitigation. Each one's AI search leads to a lot of energy consumption. This research also throws up some interesting solutions regarding climate change in a VUCA (volatile, uncertain, challenging, and ambiguous) world like having global teamwork, scenario planning, and systems thinking. Some practical solutions include Transition to Renewable Energy, Reforestation, Public Awareness and Education, etc.

Keywords – Climate Action, Artificial Intelligence, Sustainable Development Goal 13, VUCA, Public Awareness.

Using the VUCA model, it is certain that climate change is volatile, uncertain, complex, and ambiguous. The fast pace of change within the environment sows volatility, uncertainty over the right course of action, complexity of issues of climate with each other intertwined, and ambiguity of efficient solutions all speak to the enormity of problems world leaders face. Air pollution in urban metropolises like Mumbai, Bengaluru, and other cities in various developed countries, in one way or another, tends to be a part of deforestation or clear-cutting, urbanization, and industrialization which have contaminated the urban air of metropolises like Mumbai and other cities, but burdened the ecosystems of the entire world. Briefly, climate change is fuelled primarily by coal, oil, and gas, which cumulatively produce more than 75% of all the greenhouse gases on the planet and nearly 90% of carbon dioxide emissions. Governments, businesses, and individuals need to address climate change. However, the effort to avoid these energy sources remains one of the biggest hurdles, especially for the Developing Nations in the Global South. They depend on fossil fuels to stabilize their economies; however, they lack the money, the worst technology, weak infrastructures, and very few experts in that area.

It is in this light that it presents the challenge and opportunity to integrate AI and climate action. For example, AI is part of the transition changes in sustainability as it ensures consumption and efficiency in energy, optimizes renewable energy systems and creates predictive models that make an area climate resilient. This must be matched with responsible practice in carbon foot printing of AI technology, green computing, and ethical frameworks for sustainability.

This balance between AI-based innovation and environmental protection is crucial in turning technological progress from an antagonist against the planet into its assistance. AI capabilities focused on general goals around climate for this VUCA world such as **SDG 13: Climate Action** will most likely bring revolutionary transformations. Collaborations globally, and equalizing policies for responsible uses by societies would empower them in forming a future built upon resiliency and sustainability.

Literature Review

AI in Education

The paper by Jagadeesh Kengam (2020) brings into view, quite excellently, the rate of the adoption usage of AI technology in the learning spaces within the area of education. Huge uptakes in learning AI spaces with projection according to the 2018 Horizon report. Estimated

growth from \$1.1 billion in 2019 and as expected by 2030 will amount to about \$25.7 billion. Besides education, other benefits of such education include the learning of personalization and intelligent tutoring systems besides administrative efficiencies. The above paper cited reports that this education benefit encompasses high levels of engagement through students, on-time feedback that allows automatic marking, and a huge free time for instructors and students. But as the paper postulates in the tail-end, "it has also some drawbacks in itself; the interpersonal communication goes against it, makes a man technology addict and betrays one's privacy." Then Kengam concludes very convincingly to present educational bodies by using AI in a way for enabling and not replacing the teachers where strategic implementation yields maximum rewards with minimum dis-benefits.

Conservation Practice in a VUCA World

The article by Schick (2017) demonstrates the conservation practice associated with performance in the VUCA framework. The research paper suitably fits in the list of adaptive management eventually needed to retain changes within Earth's atmosphere. The same conducted studies with the help of 524 respondents within the age category and above who are from 22 sites spread across four diversified continents.

It used the MARISCO framework in class. Greater awareness of the impacts of global climates on ecosystems and cooperative-focused management strategies became value additions that have been pursued. This is an alarming holistic conservation practice on the impacts of local knowledge and adaptive strategies that advised this paradigm shift, recommending long-term research about it on global environmentalism.

Climate Changes Due to AI and Its Adaptation Strategies

The newest promising adaptation under climate conditions is supported by the appearance on the pages of Technological Forecasting and Social Change, where Walter (2022) systematically reviews an elaborative questionnaire carried out among interested researchers about climate change. Among them, one prominent finding has been reported that, according to them, predictive models have improved very much in furthering strategic adaptation in vulnerable areas. Artificial Intelligence assures resource management at a very effective level, and it is, therefore, delivering knowledge data concerning policies related to its development. It discusses how the artificially intelligent solution regarding climate change plays an important functional role for an article by proceeding towards more strides concerning climate change in a paper on "Artificial Intelligence-Based Solutions for Climate Change" in Environmental

Chemistry Letters. It bridges parts of deficiencies for optimization concerns about the utilization of energies within the horizon of the building and industry processes and scopes within plans better in terms relating to weather prediction, smart-grid, and the carbon emissions throughout efficient transportation. The phenomenal reductions in carbon footprints through the smart applications of this app are assuredly much bigger.

AI & Climate Change: Advanced Modeling & Environmental Near Real-Time Tracking

This journal is presented by Chen, L (2023) in this paper, which is under the heading "AI for Climate Change: Enhancing Predictive Models for Climate Patterns and AI-Driven Environmental Monitoring, in the Journal of Emerging Technologies and Innovative Research. The algorithms mentioned in this paper are high-level ones of machine learning that enhance the quality aspects of a climate forecast prediction and then integrate, in real-time, data from the sensor placed within far-flung regions and images which give an insight into changes occurring within the environment in real-time. This also depicts how AI is helping in predicting extreme climatic conditions so that disaster preparedness and response can be upgradable to take suitable measures finally against the negative impacts of climate change.

Conservation and Sustainable Development in a VUCA World

The paper Conservation and Sustainable Development in a VUCA World: The Need for a Systemic and Ecosystem-Based Approach was presented by Rana Afreen Sheikh (2024) The presentation of the task is what should be done by exploiting the process outlined in MARISCO if the problem of achieving the conservation and sustainable development of the world in the shadow of the VUCA world is to be solved. This responds to the stimulus of a system and the adaptive demands resulting from climatic change because it is at present possible, through the coming together of data tapped from 22 sites around four continents that deliver on time underpinned on the way functional ecosystems get together when constructing human wellbeing in positive ways. Similarly, these lesser conservation sites, articulating an equal and simultaneous demand for active management of risks have in turn also been able to necessitate cooperative management by other lesser conservation sites.

This book views AI for the decisions that are made in conditions of VUCA for sustainable development. Reflections on decisions for sustainable development by AI in the VUCA framework: A systematic literature review using a bibliometric analysis paper abstract was presented by Nikseresht, A (2022). It outlines the overview of how AI tools may assist in aiding the process of the decision through analysis and giving feedback on the vastness of the kind of

system. Its contribution towards even the conceptual elements, even in practical application, goes to strengthen further sustainable development with planning in further research along with policy formulations.

Effect of Annealing Temperature on CuFeS₂ Nanoparticles

The title "Effect of Annealing Temperature on the Structural and Thermoelectric Properties of CuFeS₂ Nanoparticles Prepared by the Hydrothermal Method" by Friederike (2024) is the published paper synthesized by ScienceDirect; perhaps it can impactors for the thermoelectricity properties, as such synthesized and characterized CuFeS₂ nanoparticles under various annealing conditions. These were characterizations that had gone into phase structure determination by XRD and also functional groups and thermal stability, all analyzed individually with the help of FTIR and TGA. The results indicate that annealed samples of CuFeS₂ are a product of the treatment by annealing presented and thus should be the top contender for use in this line of thermoelectricity.

AI Predicting and Climate Impact

Application Review: by Mankala (2023) Climatic Change Predictions and Its Impact on Hosts of the Participants of 2023 IEEE 5th International Conference on Cybernetics, Cognition, and Machine Learning Applications (ICCCMLA) - Artificial Intelligence and Climate Change Prediction. A very interesting paper relating to other species of artificial intelligence other than this related to ecological monitoring. Even for the applied climatic condition simulation and weather prediction at least involving some machine learning algorithm and artificial neural network and extraction technology. Given these facts of climatic climate improvement, which is especially specific in reproducing any scenario for the most extreme condition that might apply to sea rise and changing an ecosystem, it is on which this paper deems the topic of AI-based solutions. It is a discussion about the challenges and morality of AI in climate science.

Climate Change and AI: A Critical Review of the Global Research Ecosystem:

Covering the boundary world of AI and climate research through its paper, "Climate Change and Artificial Intelligence: A Critical Review of the Global Research Ecosystem.". This paper reviews the uses of AI methods in climate-related research and that of leadership countries with a newly merged corpus of scholarly literature. It has published research work and funding within the intersection of AI in climate in top-ranking institutes in China. Chances include gaps in time-series data improvement in climate system modeling; and estimation of inventories of

emission. Core gaps are approaches and refinement in climate scenario projection. This workable core gap from the AI extension toward climate research makes knowledge long-needed by researchers and policymakers.

Research Objectives

1. To examine the relationship between B.Ed. Students' perceptions of AI's advantages for environmental sustainability and their belief in its role in addressing climate change.
2. To determine how B.Ed. Student Teachers view AI's contribution to combating climate change.

Research Hypotheses

Hypothesis 1: Descriptive Hypothesis: B.Ed. Student Teachers believe that AI developers can design solutions to mitigate the problems of climate change.

Research Methodology

For conducting this research, the survey method was used as the primary source of data collection. The survey was conducted on a diverse set of respondents. The students of various B.Ed. Colleges were targeted. Participants from multiple B.Ed. Institutions, focusing on climate change, capturing diversified views and personal experiences on matters to do with the application of artificial intelligence and its presumed potential to play a role in addressing climate issues. This was an important process; not only a more extensive view towards the topic assurance and comprehensive research understanding but also made the research full of inspiration from those leading minds actively playing their roles towards influencing the eventual outcome for the future generation.

A descriptive survey methodology is proposed to research the perception of student teachers of B.Ed. in Mumbai about AI's contribution in trying to mitigate climate change. A structured questionnaire was administered to 109 student teachers online and offline, which gathered quantitative data concerning the usage level of AI tools by the student teachers, views of student teachers concerning climate change issues, and student teachers' opinions regarding the potential of AI regarding the mitigation of these issues. The data was analyzed using descriptive statistics to summarize responses in correlation analysis and to establish a relationship between the general acceptance of AI in utility for environmental sustainability as it relates to how the importance of AI in climate change solutions is being accessed. Random sampling was used to

ensure that a representative sample was given to produce reliable and valid findings. The questionnaire was pilot-tested to avoid biases in such and to correct them. Neutral word choice, free from leading questions, was taken to set up the survey by promising anonymity. In this case, there is an efficient way of collecting and analyzing data because it used software in the creation of the survey and its later analysis using statistical software. It was chosen since it was pretty efficient in extracting data from many respondents and in producing measurable, comparable data amenable to statistical analysis for the derivation of meaningful conclusions. Hence, the research will use these methods to come up with a comprehensive understanding of the opinions of B.Ed.

Research Design

1. Type of Design: The descriptive survey research is the *present study and measurement and analyses of the perception of student teachers who are going for their B.Ed. From Mumbai regarding the role of Artificial Intelligence in Climatic Change have been done .

2. Sampling Strategy and Sample Size: The sampling scheme adopted for present study was - random sampling to involve the representative sample of the BEd students teachers. The whole sample size is composed of 109 student teachers who have participated in the research.

3. Data Collection Method (Survey): The data collected in this study was gathered using a structured questionnaire that was used in both online forms, which is the way that the quantitative data was collected from the student teachers.

4. Data collection tools-Instrument (Questionnaire): The questionnaire comprised mixed questions like mcq , linear, etc. The Questionnaire was structured in a way devised to cover all the information, under three heads in the general area: Extent of use of AI tools used by the student teachers. Views of climate change issues among student teachers - Opinion relating to climate problem-mitigative capabilities, -ability of AI. Questionnaires were pilot-tested for the above possible bias and to give further clarity. Neutral wordings have been adopted to avoid leading questions for objectivity. The guarantee of anonymity will motivate respondents to provide honest answers.

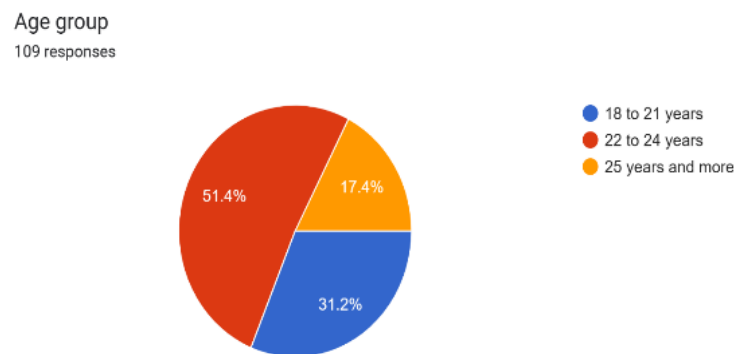
5. Procedure to Describe the Data Collection Method: During data collection, a software was used to design and develop a questionnaire, so that the data collection is streamlined.

The questionnaire was administered online with the aim of reaching a high number of student teachers. Analysis of the response used descriptive statistics, which incorporate correlation

analysis to the extent of determining whether acceptance of AI relates to its function in climate change mitigation. The data analysis was conducted using statistical software to produce measured and comparable results for meaningful conclusions.

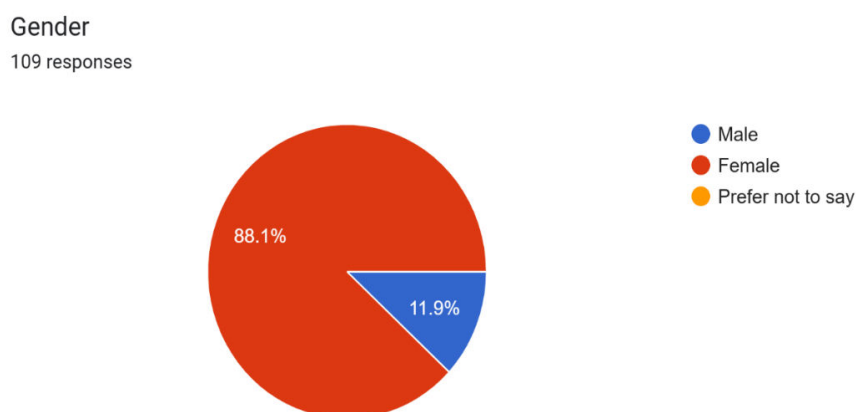
Data Analysis Of The Collected Data

The Sample: AGE GROUPS of BEd Students from three Universities in Mumbai



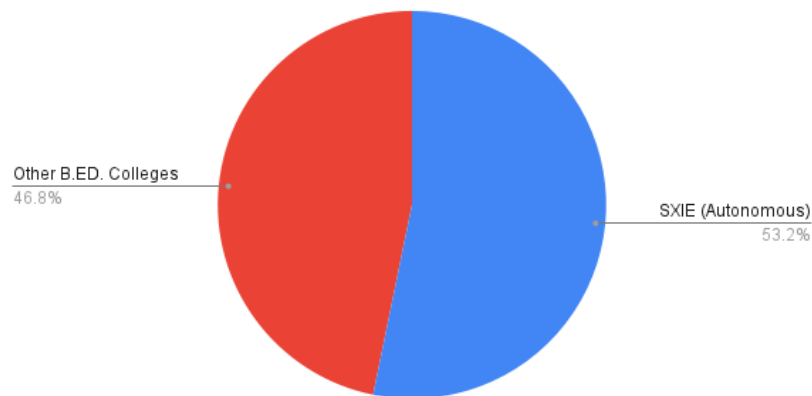
Most respondents to the survey were aged between 22 and 24 years which made up **51.4%** of the sample. This was followed by the 18 to 21 age group which earned 31.2% and the least proportion was for those who were aged 25 and above at **17.4%**. For more detail, the polling insight for the younger adult population, specifically those aged between 22-24 years old shows a tremendous level of interest and participation in combining Artificial Intelligence with the efforts devoted to combatting Sustainable Climate Change.

The Sample: GENDER of BEd Students from three Universities in Mumbai



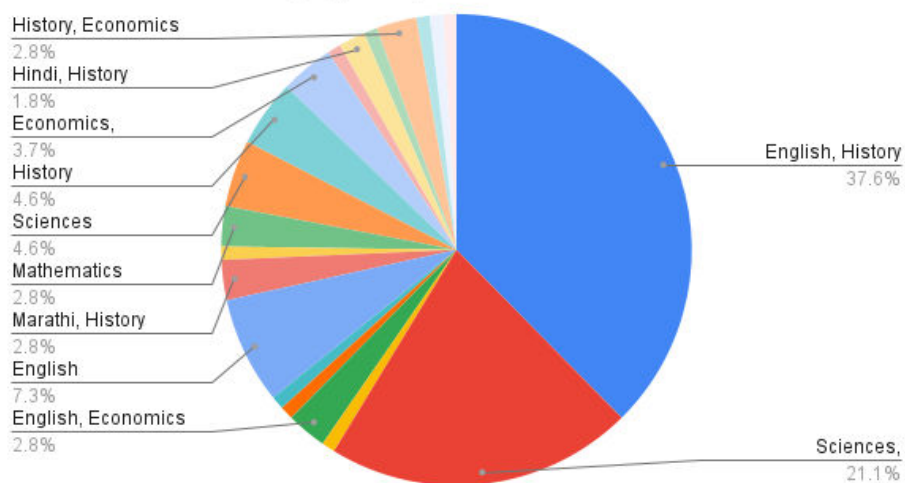
It is evident in this survey that a great number of participants were dominantly women accounting for roughly **88.1%** of the data whereas men only made a minimal contribution of about **11.9%**. Such a huge gap in the relative representation of genders indicates a great tendency to engage with the survey responses since women tend to engage more when the topic concerns Artificial Intelligence and Sustainable Climate Change.

The Sample: BEd COLLEGE GROUPS of Students from three Universities in Mumbai



At least 53.2 % of the respondents were from St. Xavier's Institute of Education (Autonomous), affiliated to the University of Mumbai; whereas 46.8 % of the respondents were from other B. Ed. colleges in Mumbai, affiliated to the three Universities, i.e. the University of Mumbai, the Homi Bhabha State University and the Hyderabad and Sind National Collegiate University, in South Mumbai..

Count of B.Ed Pedagogy Subjects

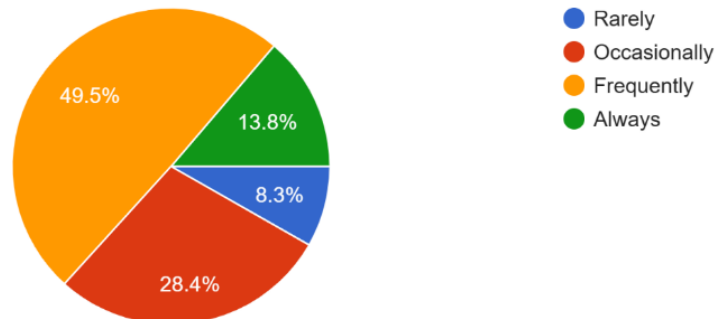


The data reveals that the most chosen subject combination is English and History, which gained **37.6%** of total selections. Next to it, 'Sciences' is the second subject at **21.1%**. With English and History dominating, other subjects that are marginalized herein include Mathematics, English, and Marathi-History, English-Economics as they each gain **2.8%**, and Only English gets **7.3%** on its own.

The extent to which Mumbai BEd Students use Artificial Intelligence (AI):

1. How often do you use AI (Artificial Intelligence) ?

109 responses

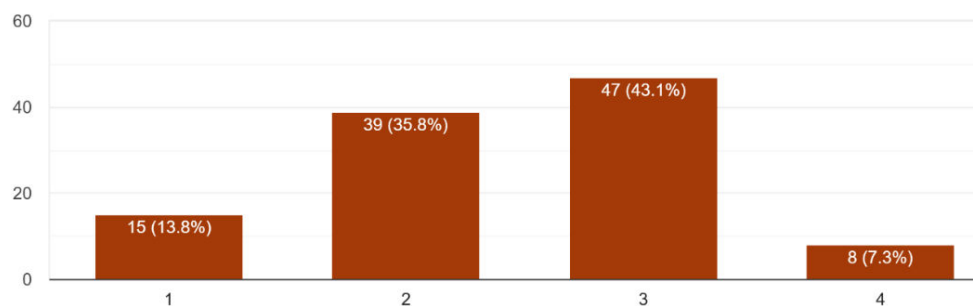


The figures demonstrate that 63.3% of Mumbai BEd Students use AI, sometimes; while at least 36.7% indicated they regularly use AI, and these are the experts, researchers, or tech enthusiasts who depend on AI outputs. There are apparent barriers, of perhaps not knowing; perhaps not gaining access; and some perhaps distrusting AI. The usage of AI can be improved by education about AI that more people can use and benefit from.

Rating one's awareness of VUCA

2. How would you rate your awareness of the VUCA (volatility, uncertainty, complexity, and ambiguity) framework in relation to climate change challenges? (1 means less and 4 means more)

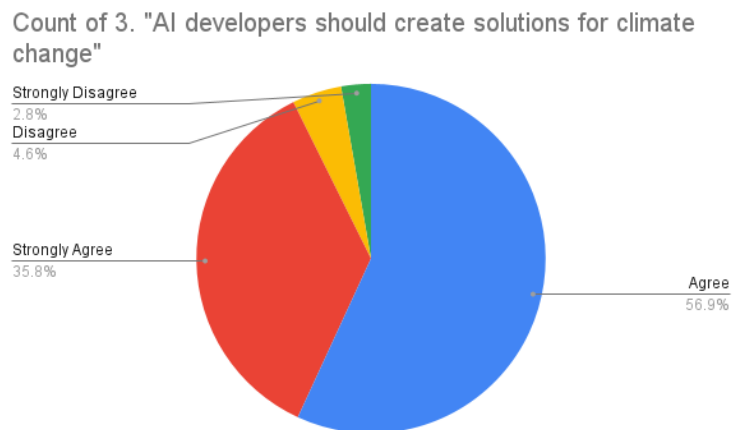
109 responses



Average Rating (2.44)

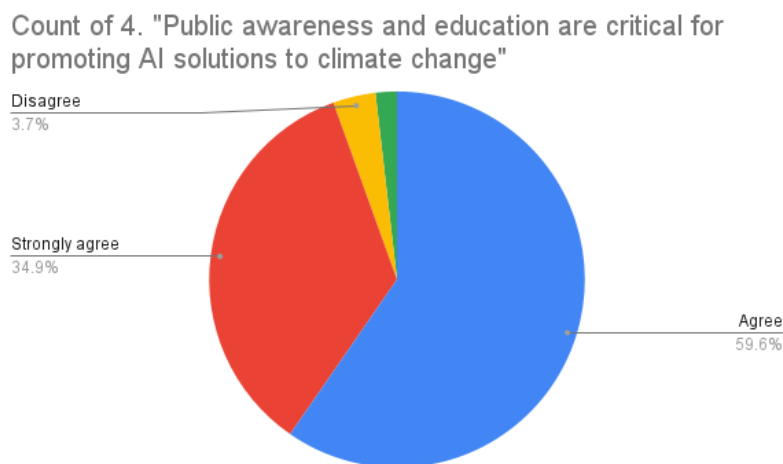
A score under 3 points out that a lot of B.Ed. Student teachers haven't gotten into VUCA when they think about climate change. Findings indicate we have to move further into the VUCA mindset to do better at planning and to be tougher in the face of climate change.

BEd Students opinions that “AI Developers should create solutions for Climate Change”



At least **92.7%** B.Ed. Student teachers affirm that AI developers should focus on developing solutions that would ultimately solve climate change. A very few **7.3%** disagreed with the statement; they may think that the proposal is impossible, ineffective, or (for some other reason) morally wrong to use in the fight against climate change.

BEd Students opinions that “Public awareness and education are critical for promoting AI solutions for climate change”

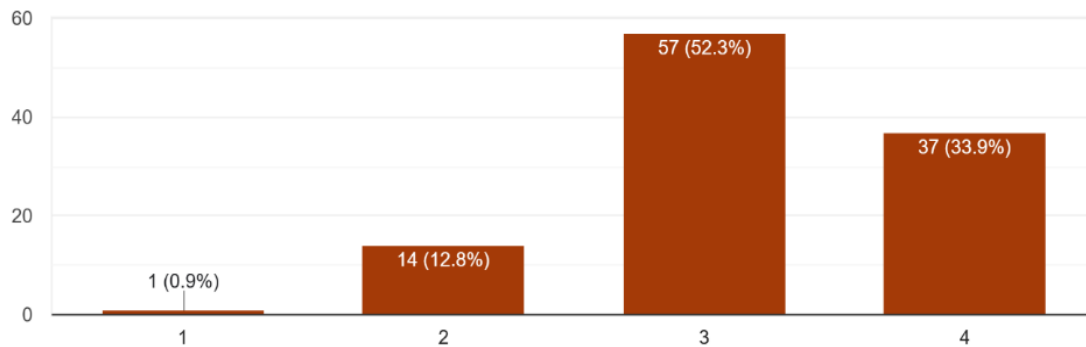


At least 94.5% of BEd Students feel strongly that public awareness and education are critical for promoting AI solutions for climate change. About 5.5% are skeptical about public awareness and education being the significant components that will drive AI solutions for addressing climate change issues. Such an indication indicates that people are optimistic and can place trust in the power of education to influence acceptance and implementational activities based on AI technology for environmental sustainability.

BEd Students assertions about “Supporting policies that integrate AI with sustainable energy solutions”

5. How likely are you to support policies that integrate AI with sustainable energy solutions? (Score 1 means 'Less Likely' and Score 4 means 'More likely')

109 responses



Average Rating

Average High Rating: An average rating of 3.19 tends towards supporting the policies that would have AI complemented by solutions for sustainable energy. That is, generally speaking, people favor such policies rather than not.

86.2% of respondents show a positive rise towards AI and Policy implications, indicating comprehensive support and excitement about the coupling of AI with the solution for sustainable energy.

AI Implications for Policy Makers:

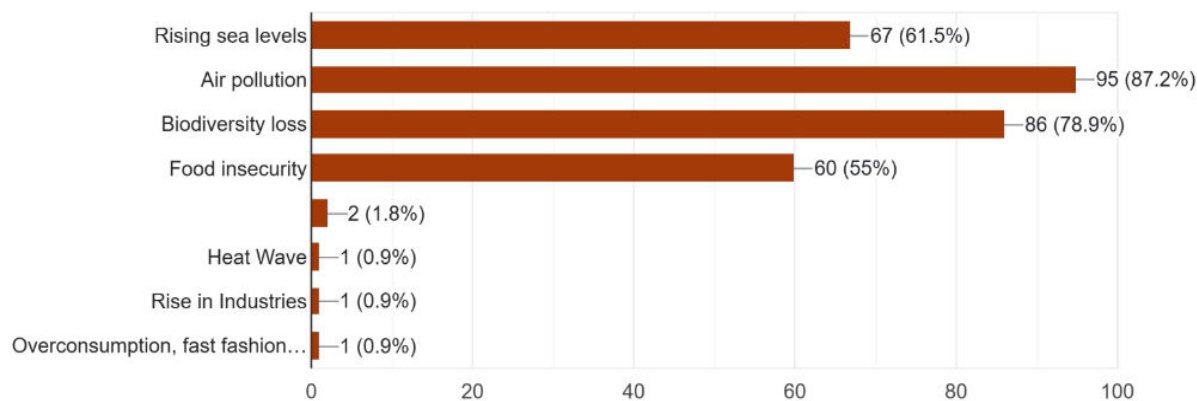
Policymakers can involve more with the people who have questions in their heads so that a better understanding might come over those concerns along with the facts on the brighter sides and downsides of integrated AI with energy sources.

The attitude of the respondents toward the policies that integrate AI with the sustainable energy solution is rather strong 3.19 out of 4 in terms of average rating, according to the survey. Such positivity towards such policies does point to public awareness of how much aid AI can bring in the way of sustainability of energy resources.

BEd Students selections of the most pressing problem resulting from Climate Change

6. What do you consider to be the most pressing issue resulting from climate change? (Please select all options that are applicable.)

109 responses



Air Pollution: 87.2% of B.Ed. Student teachers said that air pollution was the major problem brought about by climatic change. The quality of air deteriorates, causing serious effects on human health, affecting the respiratory system, low life expectancy, and worldwide warming.

Loss of Biodiversity 78.9% of B.Ed. Student teachers said it undermines the sustainability and resilience of ecosystems leading to species extinctions and upsets natural processes. It is very alarming in so far as food security, quality of water, and general health of the planet.

Rising Sea Levels 61.5% of B.Ed. Student teachers agreed that high sea levels threaten the coastal communities, floods, erosion, and displacement of the population; due to melting polar ice caps and glaciers along with the thermal expansion of water seawater in the world.

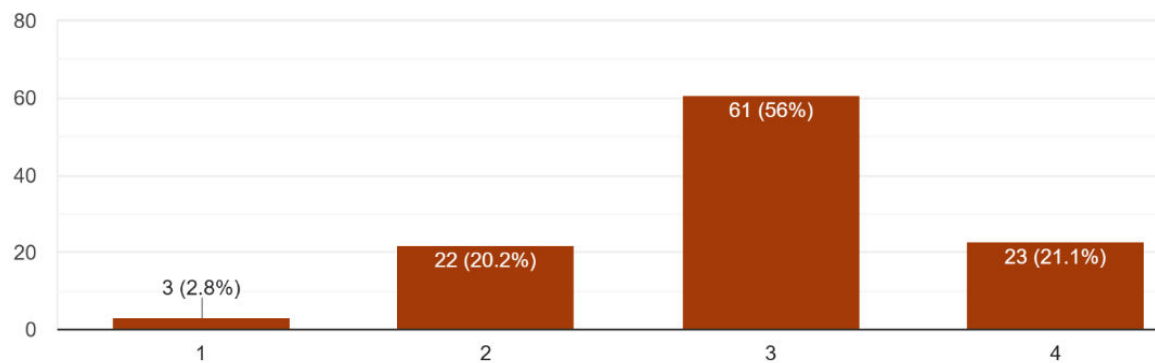
Food Insecurity: 55% of B.Ed. Student teachers said that the level of food insecurity has risen agriculturally, impacting productivity and threatening food supply chains leading to high prices of foodstuffs as well as a likelihood for hunger and malnutrition.

Other Issues: 4.5% of B.Ed. Student teachers point out heat waves, rise in industries, overconsumption, fast fashion, etc as the issue. Despite this being a relatively low number when compared to other issues raised, climate change causes higher frequency and intensity of heat waves which threatens serious health dangers in vulnerable populations with increased death rates beyond the pressure on the health care system.

BEd Students opinions about “Effectiveness of AI technologies in Mitigating Climate Change”

7. How effective can AI technologies be in mitigating the effects of climate change?

109 responses

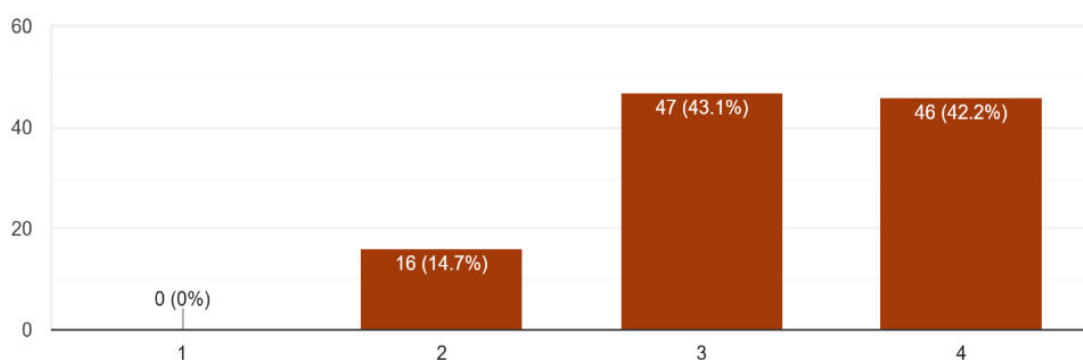


At least **23%** BEd Students ranked AI technologies as least or less effective in fighting climate change. They may see some promise in AI but will be worried by the general effect and problems of its application. At least **77%** of respondents rated AI technologies highly and may feel that AI may turn out to be a supporting tool in pursuing the reductions necessary with climate change, but still consider that something supplementary or more extensive research may still be required.

BEd Students opinions about “The importance of Global Collaboration in developing AI Driven Climate Solutions”

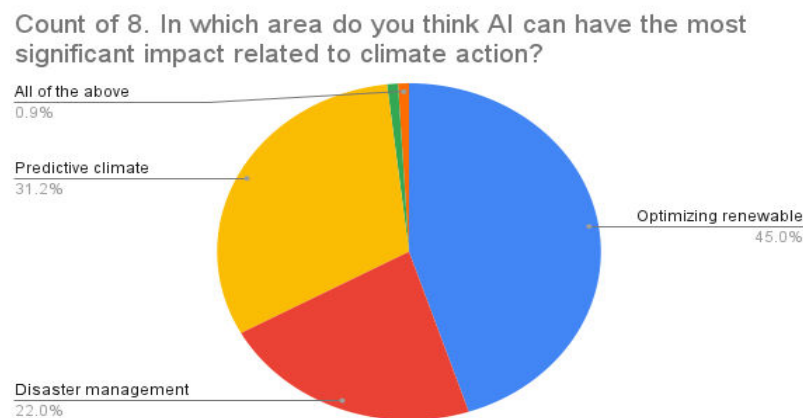
9. How important is global collaboration in developing AI-driven climate solutions?

109 responses



At least **85.3 %** are interested in initiatives that also reflect individual or regional interests. They regard international collaboration to be very indispensable to the actual development and implementation of AI-driven climate solutions.

BEd Students opinions about “Areas in which AI can have the most significant impact related to Climate Change”



Respondents felt AI could most help with climate action: Optimizing Renewable Energy Systems, Disaster Management, and Predictive Climate Modeling.

(a) Optimizing Renewable Energy Systems:

45% of the respondents are keen on optimizing renewable energy systems, by being able to transform renewable energy into a source such as solar, wind, and hydroelectric power. Further optimization of this aspect increases the improvement of energy production, storage, and distribution toward more sustainable and reliable sources.

(b) Predictive Climate Modeling:

31.2% of the respondents feel AI's impact will be tremendous in predictive climate modeling. AI-based predictive models can forecast climate change with high accuracy; they can tell the impacts of climate change and how to control them. This will help build strategies for preparation for disaster, resources, and long-term environmental planning.

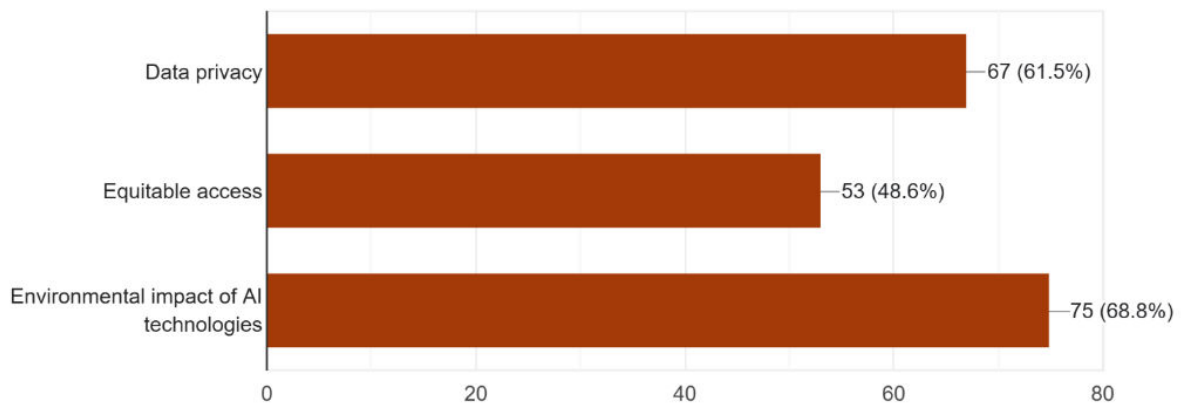
(c) Disaster Management:

22.0% agreed that the impact of AI in disaster management is enormous. The real-time analysis of data might help give early warnings and allocate resources while responding to and recovering from disasters, something much more contributed by AI technologies. It may even let a better control of natural disasters such as hurricanes, floods, or wildfires. That will further reduce its impact on communities and ecosystems.

BEd Students' "Concerns regarding ethical implications of AI in environmental solutions"

10. What concerns do you have regarding the ethical implications of AI in environmental solutions?
(Select all that applies)

109 responses



At least **85.3%** rated collaboration at a score of 3 or above. This means that the majority of the student teachers of Mumbai B.Ed. Colleges appreciated the importance of global collaboration in the role of mitigation of the global nature of climate change. This was to determine which of the critical ethical concerns is provided by the B.Ed. Student teachers about AI use in environmental solutions. Data Privacy, Equitable Access, Environmental Impact of AI Technologies, and Others were the options available.

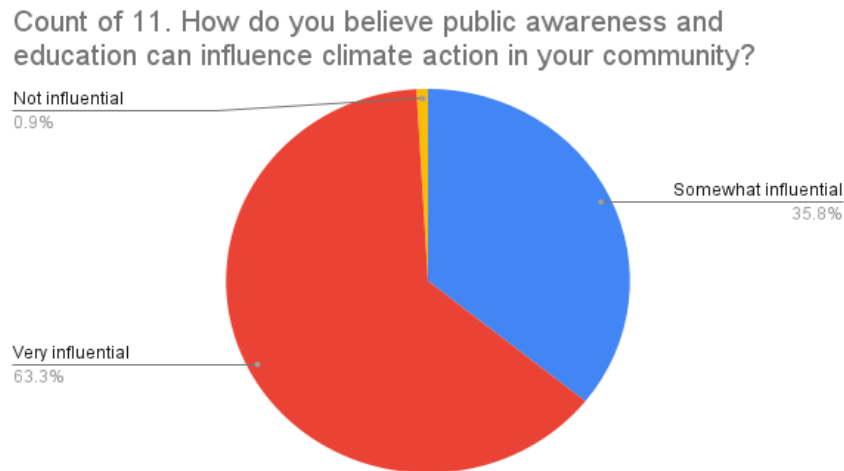
Environmental Impact of AI Technologies: The highest-ranked concern of the survey is environmental. **68.8%** said this was the case. The reason for this is how people fear what may be true regarding environmental degradation and issues; such concerns about power consumption and waste in electronics, as well as carbon prints created by infrastructures associated with AI, arise. People may fear that the positive environmental impact expected from AI implementation may be erased.

Data privacy: **61.5%** of the respondents said they care about data privacy. This highlights the need for the protection of personal and sensitive information in developing and implementing AI-based environmental solutions. Data is an essential aspect of AI, where it collects and analyses large data sets; however, it should be managed responsibly so that it doesn't compromise the individual's privacy and misuse data.

Equitable Access: **48.6%** said they are concerned that AI technologies will not be shared equitably. Again, this is about access to AI-based environmental solutions across all

communities based on their socio economics or locality. Access will be drastically important in preventing disparities and rather equitable delivery of benefits for different populations.

BEd Students opinions about “Whether Public Awareness and Education can influence Climate Action in ones Community”



Very Influential: 63.3% B.Ed. Student teachers claimed that public awareness and education influence a great extent of the action taken on climate in the respondent's community. This is pretty high; therefore, citizens will play much more critical roles in determining if there is a need and drive toward sustainability oriented practices. Public awareness campaigns and education programs, as a result, will be on follow through to augment this participation and support towards undertaking actions on climate.

Somewhat Influential: 35.8% of student teachers also believe that awareness, publicity and education are somewhat influencing. This group knows how effective and successful creating awareness and performing education can be, however, they appear to only consider the policymaking, technological advancement, and initiative by people as having substantial influence in impelling climate actions.

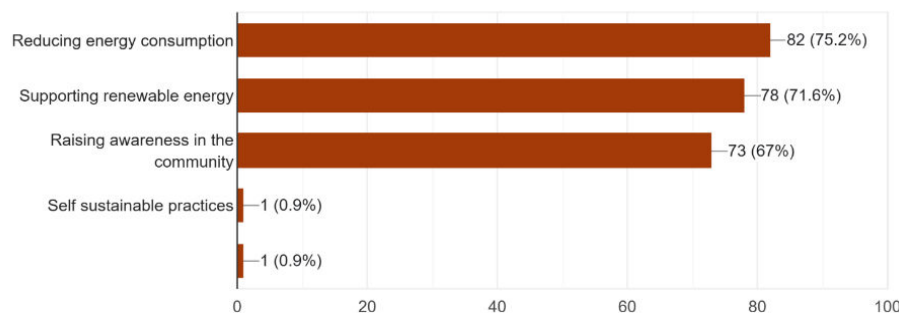
Not influential: Only a minimal **0.9%** of the student teachers consider public awareness and education as not a leading factor. A total of **99.1%** reported such efforts as very influential or somewhat influential in controlling climate change.

There is a critical need to invest further in education programs as well as education campaigns because they are most probably going to infuse people with the right knowledge as well as incentives to take appropriate measures against climate change. That is the reason why this role of making policies, guiding teachers, as well as influencing other local leaders will be how to

channel influences towards creating suitable ways of sustainability and resilience in the environment.

BEd Students contributions to mitigate Climate Change

12. What actions do you personally take to contribute to climate change mitigation? (Select all that apply)
109 responses



This question determines what personal actions the student teachers would like to take, to help in mitigating climate change: Reduce Energy Consumption, Support Renewable Energy, Raise Community Awareness, and Other.

Energy Consumption Reduction: A majority, **75.2%**, indicated that they are taking steps to decrease their consumption of energy. The percentage is highly significant, meaning that there is a lot of concern about reducing energy consumption, and a lot of greenhouse gases will be saved in the environment. Such practices can be that of using appliances that consume much less energy, consuming much less electricity, and being a conservation practice.

Boosting Renewable Energy: **71.6%** of the respondents affirmed having supported renewable energy sources. Support could be in the manner of investment, policy support, or choice to use renewable in homes and enterprises. The high percentage of support indicates the need to shift towards clean renewable energy and mitigate climatic change.

Sensitization in the Community: **67%** of them are currently raising awareness of climate issues within their community. This activity typifies education and advocacy as means of motivating people toward unified action. Through this, the respondents inform and involve others in an attempt to further the understanding of climate issues and galvanize community-wide actions toward reducing climate change.

Other Activities: A very low percentage, **1.8%**, of the student teachers selected "Other" as a range of individual efforts not categorized in the options above. Although the percentage is

very low, it at least suggests that some future teachers are doing something outside of these categories to address climate change.

The most common personal actions student teachers have undertaken to mitigate climate change are reducing their energy consumption, supporting renewable energy, and spreading awareness in their community. Commitment to sustainability is very evident through these actions, as they suggest that there are multiple dimensions to personal contributions to climate action. The breadth of participation in these areas indicates quite a broad potential for aggregate impact. This commitment should be seized by policymakers, community leaders, and environmental organizations to foster and support more climate action endeavors.

Solutions to Climate Change: Some of the effective solutions are listed below:

Transition to Alternative Energy Source: The utilization of renewable sources that include sunlight, wind power, and other hydroelectric generation is crucial since it minimizes the amount of greenhouse gas release. Additionally, it provides a much-needed source of employment together with economic growth economically.

Carbon Capture and Storage-CCS Technology: In many CCS technologies the CO₂, which may appear airborne in one location is grabbed before that instance.

Sustainable Agriculture: Encouraging a plant-based diet through healthy eating and promoting sustainable agriculture practices can reduce impacts from food systems. This ranges from reducing the use of fertilizers to minimizing the loss of food through waste.

Afforestation: New tree forests absorb CO₂ from the air. Afforestation can therefore restore biodiversity while creating new carbon-neutral territory.

Carbon Pricing: Carbon taxes or the cap-and-trade system allow firms to minimize their emissions by imposing a high cost of pollution. This, in turn, encourages clean technology innovation.

Energy Efficiency: Enhanced energy efficiency of buildings and industries reduces aggregate energy use, hence very significantly decreasing emissions over time. This will be through retrofitting buildings and using energy-efficient appliances.

Public Awareness and Education: The public's knowledge of the effects of climate change and its remedy can empower the public to live their lives in an environmentally friendly way. For example, minimizing waste and saving energy.

Implications of these findings in education:**Enrichment in Curriculum and teaching in education.**

1. **Introduction of AI and Climate Change Concerns:** Average perception towards VUCA has highly increased with more support being exhibited toward the implementation of AI towards easing climate change, pointing out that the two subjects require integration into the education system. That would mean an all-inclusive package with information on AI technology, use issues concerning climate problems, and any other issue covered in studying VUCA towards an environmental look, thereby bolstering the capabilities of the student in his understanding of the multi-facets of climate-related issues.

2. **Interdisciplinary Learning:** The synergies and overlaps of AI and climate change that seek knowledge from as diverse groups of fields as the areas of computer science, environmental sciences, social sciences, and many more, are liable to be big opportunities for interdisciplinary learning under which students get exposed to developing holistic solutions concerning environmentally related issues brought closer together.

Public Awareness and Engagement

1. **Public awareness and education:** Public awareness campaigns got much support since educational campaigns, awareness, and advertising of the virtues and uses of AI for action in climate also require to cross boundaries into schools and universities among other institutions, important ones are expected to take the outreach projects, workshops, and seminars to all people in the society.

2. **Community Engagements:** The community-based projects based on AI and climate change multiply bottom-line understanding of multi-sectored involvement in the student sector of the concepts and raise responsible behavior in the students. Organization-based collaboration in the experience of service-learning projects and internships provides active participation in sustainable development.

Solutions to Ethical Problems:

1. **Responsible AI Education** Issues are graver in nature since they have matters concerning environmental degradation and may find their ways out of such AI technology used, breaches of privacy relating to information, and the issue of equities in terms of access than ethics in AI education curricula applied becomes a call upon itself. That would only mean, at the juncture,

curricula set for education shortly should therefore include modules from AI ethics, sustainable development, and the application of proper procedures in the handling of data by concerned developers and applicants.

2. Equity and Inclusion: All students should have equal access to AI technologies and education. Colleges and universities must take very seriously how they would provide equal resources and opportunities concerning the socio-economic status of the students in approaching learning AI and climate change. This would mean basic easy access to technology training and support, with added 'bridging of knowledge'.

1. Research and Advocacy: The institution will in this formation of the policy set up policy research on whether AI can reduce the issue of climate change through evidence-based advocacy letting the academia, the governments, and industries walk hand in hand towards translating findings into policies to be placed for promotion of sustainable development.

2. Prepared Leaders: The discussions on AI and climatic change in the learning promise readiness of the developing world leaders qualified and positioned adequately on the environmental change expectations of the future. Bound to come forth a leader that grabs one of these extremely influential though practical in all these ranks to make it urgent and compelling in making one innovative with the differences for survival in the operation environments.

This will unlock this massive potential significant role that education can play in the transformation process of AI-driven climate solutions all while redressing ethics concerns. This is possible not only in enrichment and equity concerns in policymaking but also through developmental assistance as well as the final one developed by public enlightenment through education systems. More aware, mobilized, and participating citizens in an even stronger situation and ready to face the challenge that climatic change poses now.

Conclusions

The research concluded, with the idea of the need to Align AI with the application of sustainability for climate change concerns in this world of being VUCA. The VUCA framework reveals challenges in dealing with climate change- this involves speed shifts in environments, which make complexity unique for decisions for leaders when managing these scenarios. Scenario planning and systems thinking have been required as tools of such navigation. Huge impacts on the achievement of climate resilience, maximum energy

efficiency, and technological equity will be made possible through AI-driven innovations. The study assumes that the integration of AI into sustainability can shift the needle further on Sustainable Development Goal 13, focusing on climate action by advancing AI-based predictive climate modeling, improvements in systems on renewable energy, and capacity building in disaster management efforts. Findings from a survey of 109 B.Ed. Students in Mumbai reveal that public awareness, education, and individual actions, such as reducing energy consumption and adopting renewable energy, are crucial to mitigating climate change. It is the research that calls for collaboration at the international level and urges that the remedy to climate change lies in making technological progress commensurate with the protection of nature so that this planet can survive for generations ahead.

References

1. Mirror, M. (2023, November 5). Mumbai is very vulnerable to climate change, and we must learn to adapt. *The Times of India*.
http://timesofindia.indiatimes.com/articleshow/104981640.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst
2. World Bank Group. (2023, March 31). *India: Climate change impacts*. World Bank.
<https://www.worldbank.org/en/news/feature/2013/06/19/india-climate-change-impacts>
3. Sah, P. (2024, September 18). *India experiences the second hottest period since 1970 due to climate change*. The Hindu. <https://www.thehindu.com/sci-tech/energy-and-environment/india-experiences-the-second-hottest-period-since-1970-due-to-climate-change/article68656779.ece>
4. How to solve global warming: Challenges & solutions. (1 B.C.E.). *Leaf by Greenly*. Retrieved January 16, 2025, from <https://greenly.earth/en-gb/blog/ecology-news/are-there-any-global-warming-solutions>
5. Artificial intelligence in education. (2020). *ResearchGate*.
https://www.researchgate.net/publication/347448363_ARTIFICIAL_INTELLIGENCE_IN_EDUCATION
6. Schick, A., Hobson, P. R., & Ibisch, P. L. (2017). Conservation and sustainable development in a VUCA world: the need for a systemic and ecosystem-based approach. *Ecosystem Health and Sustainability*, 3(4). <https://doi.org/10.1002/ehs2.1267>
7. Deploying artificial intelligence for climate change adaptation. (2022). *ScienceDirect*, 180(121662). <https://www.sciencedirect.com/science/article/abs/pii/S0040162522001949>
8. Chen, L., Chen, Z., Zhang, Y., Liu, Y., Osman, A. I., Farghali, M., Hua, J., Al-Fatesh, A., Ihara, I., Rooney, D. W., & Yap, P. (2023). Artificial intelligence-based solutions for climate change: a review. *Environmental Chemistry Letters*, 21(5), 2525–2557.
<https://doi.org/10.1007/s10311-023-01617-y>
9. Shaikh, R. A., Khan, S. K. S., Golhar, S. N., & Nasim, M. (2024). AI FOR CLIMATE CHANGE: ENHANCING PREDICTIVE MODELS FOR CLIMATE PATTERNS AND AI-DRIVEN ENVIRONMENTAL MONITORING. In *Journal of Emerging Technologies and Innovative Research (JETIR)*, *Journal of Emerging Technologies and Innovative Research* (Vol. 11, Issue 10). <https://www.jetir.org/papers/JETIR2410455.pdf>

10. Schick, A., Hobson, P. R., & Ibisch, P. L. (2017b). Conservation and sustainable development in a VUCA world: the need for a systemic and ecosystem-based approach. *Ecosystem Health and Sustainability*, 3(4). <https://doi.org/10.1002/ehs2.1267>
11. Nikseresht, A., Hajipour, B., Pishva, N., & Mohammadi, H. A. (2022). Using artificial intelligence to make sustainable development decisions considering VUCA: a systematic literature review and bibliometric analysis. *Environmental Science and Pollution Research*, 29(28), 42509–42538. <https://doi.org/10.1007/s11356-022-19863-y>
12. Broadening the perspective for sustainable Artificial intelligence: Sustainability Criteria and Indicators for Artificial Intelligence Systems. (2024). *ScienceDirect*, 66(101411). <https://www.sciencedirect.com/science/article/pii/S1877343523001586>
13. *Artificial intelligence (AI) and the prediction of climate change impacts*. (2023, October 7). IEEE Conference Publication | IEEE Xplore. <https://ieeexplore.ieee.org/document/10346636>
14. Lewis, J. I., Toney, A., & Shi, X. (2024). Climate change and artificial intelligence: assessing the global research landscape. *Discover Artificial Intelligence*, 4(1). <https://doi.org/10.1007/s44163-024-00170-z>
15. CLIMATE CHANGE AND AI, Recommendations for government action. (n.d.). *GPAL*. <https://gpai.ai/projects/responsible-ai/environment/climate-change-and-ai.pdf>

2

The Future of Manufacturing: AI as the Catalyst for Transformation

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Abstract

After independence, India has been working hard to utilise the potential of the manufacturing sector in order to accelerate overall economic growth. But till now full potential of the manufacturing sector is not being utilised, as it still suffers from numerous problems. These problems are low productivity, high cost of operations, irregular quality control, inefficiencies in the supply chain, shortage of skilled labour, lack of innovation, and environmental issues, which restrict the growth of this sector. The traditional approaches and ancient technologies magnify these challenges, leading to the demand for analysing newer solutions. In accordance with developing technology and expanding artificial intelligence (AI), these problems can be overcome from existing issues in the manufacturing industry. The role of the Manufacturing sector in India has been investigated, along with feasible solutions that solve the challenges hereunder. AI-powered automation can tremendously improve productivity through enhanced efficiency and reduced requirements of human intervention. AI-powered quality control will help to secure product variety by real-time tracking and detection of defects; predictive maintenance stops equipment from failing and requiring repair. AI supply chain optimisation is the engine driving effective logistics operations management, while demand forecasting can allow remediation of delays or stock problems. In addition, co-bots and AI-enabled training may be a concrete way to bridge the skills gap, while AI R&D might open pathways toward innovation in green manufacturing. AI property power will set a lifetime tryst for the manufacturing into an efficiency-competitiveness-sustainability triplet.

Keywords – Manufacturing sector, Artificial Intelligence (AI), Sustainable Development, Digital Transformation.

Traditional industries such as textiles, handicrafts and metal work had existed and prospered for several generations, which comprised the vast majority of India's manufacturing sector prior to Independence. It was primarily reliant on human labour, artisan skills and produced limited quantities of goods. However, due to laws that benefited British industrial interests, these sectors saw an intense collapse with the arrival of British colonial rule. By flooding the market with inexpensive machine-made commodities from England, especially in the textile sector, the British eventually deindustrialised India and destroyed the country's handloom businesses. Manufacturing stagnation was further exacerbated by high taxes, trade constraints, and a lack of backing for indigenous industries. Despite the hurdles, Indian entrepreneurs played an integral part in the establishment of modern industries in the latter half of the 19th and the beginning of the 20th century. Early industrialisation was marked by the expansion of the cement, sugar industries and the steel industry supervised by the Tata group (TISCO, founded in 1907) and the cotton and jute mills in Mumbai and Kolkata

During the two World Wars, manufacturing experienced a brief uptick. The wartime needs briefly increased the production of goods like textiles, steel and chemicals in India. Following the wars, British policy did not support the ongoing growth of Indian businesses. Because of this, when India gained its independence in 1947, its manufacturing sector was underdeveloped, with inadequate infrastructure, a reliance on foreign technology and capital goods, a modest GDP contribution, and industry mostly concentrated in a small number of urban centres. India's industry contributed very little to the country's GDP in 1947. It made up roughly 10–12% of the GDP overall.

The nationalist movement had already accelerated industrial growth in spite of these obstacles. The Swadeshi movement was supported by leaders such as Mahatma Gandhi, who encouraged independence and domestic businesses. Policymakers and economists recognised the need of government action in building a strong industrial base. This set the stage for the government's aggressive promotion of industrialisation through planned development, the establishment of public sector enterprises, and protectionist policies to support homegrown industry in the years after independence.

The manufacturing industry saw a significant change throughout time, moving from handcrafted goods to highly automated, artificial intelligence (AI)-driven production methods. Significant changes were brought about by the introduction of machines and mass production techniques during the first two industrial revolutions. Efficiency and the volume of

commodities produced were significantly increased by these modifications. The manufacturing sector started to expand more quickly after 1956. Over the following 20 years, the sector's share of India's GDP grew. The manufacturing sector's share of GDP increased to 14–16% by the 1960s and early 1970s.

Automation and computer-controlled techniques brought about by the third revolution, also referred to as the digital revolution, increased precision as well as efficiency. The industry is currently experiencing Industry 4.0, commonly referred to as the fourth industrial revolution, which is defined by artificial intelligence (AI), the Internet of Things (IoT), and smart manufacturing.

The manufacturing sector has long been a crucial part of global economic development, driving industrialisation, job creation and technological advancement. The industrial sector is estimated to grow by **6.2 per cent** in **FY25**. Strong growth rates in construction activities and electricity, gas, water supply and other utility services are expected to support industrial expansion. Despite various challenges, India continues to register the fastest growth in manufacturing PMI. The latest Manufacturing PMI for December 2024 remained well within the expansionary zone. The expansion rate for December 2024 exceeded its long-term average, driven by new business gains, robust demand, and advertising efforts.

Nevertheless, despite its critical role, the sector is currently grappling with series of challenges. Some of the most pressing issues include low productivity, high operation costs, inconsistent quality control, supply chain inefficiencies, skilled labour shortage, limited innovation and environmental concerns, which hinder the growth of this sector. Moreover, these are worsened by the traditionally overplayed methodology and technologies enlisting an equally unbearable shift towards new solutions: Cracks exposed on the world stage of supply chain through the COVID-19 pandemic, effectively exacerbating the challenges while underlining the need for a solid level of resilience and adaptability. AI is viewable as a disruptive technology that augments the process of rapid changes in technology, which is aimed at regenerating the manufacturing processes to combat this problem. By automating operations management with AI, one may enhance productivity at the cost of human capacity. Mechanisms of the feedback circuit could maintain the quality stability of a given product with a constant defect counterrotation and operational techniques which predict maintenance may cause a decrease in idle time and repair costs. AI is likely to optimise supply chain logistics management better and prevent delays and inventory misalignment. Cobots, AI platforms, and conveyors could fill

the plush skill gap brought about by the pandemic that caused a shortage and joined AI in R&D to innovate green manufacturing processes. AI may optimise the supply chain, giving it better powers with respect to logistics management while preventing delays and inventory misalignments. In addition, cobots and AI conveyor platforms could fill plush skill gaps brought about by the skilled labour shortage pandemic; on the other hand, AI R&D will maintain innovation and eco-friendly manufacturing methods. Governments should come to the table with tax incentives for such investments in AI, improve the infrastructure, along with starting skills development programs. Initiatives by the private and public sectors to make people aware of the accomplishments of AI will lay the foundation for this change. Should these emerging technologies function to their utmost potential, it would mark the dawn of unprecedented rises in productivity, competitiveness, and sustainability for the manufacturing sector.

Literature Review

Dr S. Balasubramaniam, 2023

A research work was done by Dr. S. Balasubramaniam, entitled “Integration of Artificial Intelligence in the Manufacturing Sector: A Systematic Review of Application and Implications”. The very motive of this research was to systematically analyse and review applications and implications of AI in manufacturing industries in order to highlight problems faced in implementation and application of AI, plus the reshape lined for the very way it interfaces with firm productivity, helping to promote a boost in performance-related productivity and improvement of quality control without incurring extra costs. However, the implications of AI must be critically examined in manufacturing, including impacts that concern employment, workforce training, safety, and ethics.

Satabda Chaudhuri, 2022

Research was conducted by VIT University, Krishnan LRK, titled “*Impact of using AI in Manufacturing Industries*”. The main objective of this research was to study how AI a new technology, tends to change the trends in terms of manufacturing processes and decision making in the industry and how much profit this industry could generate using AI by providing efficient solutions. The research concluded with the fact that AI will be at the forefront in the future for decision-making and efficient manufacturing.

Tobias Biegel, Beatriz Bretons Cassoli, Felix Hoffmann, Nicolas Jourdan, Joachim Metternich, 2020

Research was conducted by Institute of Production Management, Technology and Machine Tools (PTW), Darmstadt, Germany the main objective of this research was to identify the operational, tactical, strategic elements in developing and implementing AI in manufacturing companies and to introduce a new standardized more structured model in manufacturing, and developing tools and support for the implementation of AI projects in production. This paper introduces AIMM, a practical framework designed to help identify the right problem and develop AI solutions and implement it successfully in manufacturing companies. Unlike existing data mining methods, AIMM doesn't just offer a guideline but it also provides hands-on tools that makes AI adoption more straightforward and actionable.

Buch Meister, B., Palcic, I. & Ojstersek, R., 2019

Research was conducted by the University of Maribor, Faculty of Mechanical Engineering, Slovenia, titled "*Artificial Intelligence in manufacturing companies and broader: An overview*". The main objectives of this research were to examine future changes, understand AI's role, identify the opportunities and threats, assess societal impacts, decision making and efficiency.

The research concluded with the note that the manufacturing sector is a perfect fit for the application of AI. The industry 4.0 revolution is still in its early stages, but we can already witness significant benefits of AI from the design process and production floor, to the supply chain and administration. AI is meant to change the way we manufacture products and processes forever.

Methodology

In this study, we employ a qualitative research approach using case studies to explore The Future of Manufacturing: AI as the Catalyst for Transformation. The case study method allows for an in-depth examination of real-world phenomena within their natural contexts, providing rich, contextualised insights that quantitative approaches may overlook. We selected six cases based on relevance to research questions, ensuring diversity in key problems, such as low productivity and inefficiency, high operational cost, quality control issues, supply chain challenges, skilled labour shortage, limited innovation and environmental impact. Data collection involved multiple articles, academic journals and corporate records, to achieve

triangulation and enhance validity. Each case was analysed thematically using an inductive approach, where patterns and themes emerged from the data rather than being imposed a priori. The case study approach enables a nuanced understanding of the linkage between the manufacturing sector and AI, providing theoretical and practical insights that can inform policy, practice, and future research.

Discussion

Case Studies On The Various Issues In Companies Solved Through AI Integration

1. Skilled Labour Shortage – In order to minimise potential challenges caused by a lack of competent labour, Honeywell has been leading the way in incorporating AI into manufacturing procedures. Honeywell, along with Wakefield Research, worked collaboratively to conduct a comprehensive survey with 1,600 industrial AI leaders from 12 different markets around the world. The insights that have been published in the "Industrial AI Insights" study found that over 90% of AI decision-makers had discovered new use cases at multiple stages of AI implementation, yet only 17% had fully implemented their initial AI plans. Improved cybersecurity, higher efficiency, and better decision-making through real-time data generation were the main advantages identified. These results demonstrate Honeywell's ambition to the utilization of AI to improve operational efficiency and address the growing shortage of skilled workers. In a strategic attempt to expand its AI capabilities, Honeywell worked with Google to merge Google's advanced AI engine, Gemini, with Honeywell's industrial data from its Forge platform. The partnership seeks to automate tasks and shorten project timelines, tackling the industry's workforce deficit. These AI tools will aid engineers, warehouse staff, and technicians by automating tasks, handling diverse data, and boosting operational efficiency. Honeywell's customers can expect these solutions to be available in 2025.

2. Supply Chain Challenges – Ford Motor Company has been at the forefront of implementing technology such as artificial intelligence (AI) and machine learning (ML) to deal with supply chain problems. The corporation suffered serious disruptions, particularly during the COVID-19 pandemic, that exposed vulnerabilities in worldwide supply networks. Shortages of vital parts, which include semiconductors, raw materials, and other vital components, resulted in manufacturing delays, increased prices, and inefficiencies. To lessen these disruptions, Ford created a machine learning language model to predict first-tier supply chain problems. This AI-driven strategy is based on analysing massive volumes of real-time and historical data from numerous sources, including:

- a) **Capacity data** – Assessing supplier capacity and spotting potential bottlenecks.
- b) **Inventory levels** – Tracking inventory level across all supplier tiers to maintain a consistent material flow.
- c) **Utilization metrics**- Evaluating resource utilization efficiency within Ford’s supply chain.
- d) **Processing data** – Monitoring manufacturing times and identifying potential slowdowns.

By constantly analysing this data, the ML model predicts potential supply chain disruptions proactively, enabling Ford to take preventive actions rather than reacting after problems exist.

3. Environmental Impact - Tata Steel, a prominent player in the steel production business, acknowledges the significant environmental impact of its energy-intensive procedures, particularly the generation of massive carbon emissions. Driven by their commitment to sustainability, the organisation has deliberately employed artificial intelligence (AI) in order to decrease its environmental footprint and promote energy efficiency. Tata Steel leverages AI to optimise crucial components of its steel-making processes. AI algorithms utilise real-time information from a collection of sensors to fine-tune control of processes, leading to reduced consumption of energy and emissions. Furthermore, AI supports energy management by forecasting energy demand and managing energy usage across the entire site, lowering waste and boosting efficiency. The company incorporates AI for predictive maintenance, anticipating breakdowns in equipment to reduce downtime and enhance energy efficiency. These integrated AI-driven optimisations generated tremendous advantages for Tata Steel. The corporation has drastically reduced its carbon emissions, exhibiting an evident commitment to environmental responsibility. Simultaneously, they realised significant energy savings, leading in both decreased expenses and a lesser impact on the environment. Beyond environmental benefits, AI-powered process optimisation has brought about greater productivity and higher quality products, revealing that sustainability and efficient operation are possible.

4. Quality Control Issues – One of the biggest automakers in the world, General Motors (GM), had difficulties coming up with innovative ways to build vehicles, particularly when it came to lowering weight without compromising structural integrity. Conventional design techniques were laborious and constrained in their ability to explore novel alternatives. To address these challenges, General Motors implemented Autodesk’s generative design software. This AI-powered tool quickly produces numerous design options based on specified criteria such as material, weight, and strength. The modification of a seat bracket was one noteworthy

achievement of this AI-driven strategy. Previously made up of many welded sections, the AI-generated design produced a single-piece structure that was 40% lighter and 20% stronger. This not only boosted vehicle performance but also simplified manufacturing, lowering material waste and production complexity. Besides individual components, AI-driven generative design has encouraged General Motors to build lighter, more fuel-efficient, and more sustainable automobiles. By incorporating AI, the company sped up its innovation cycle, minimised expenses, and enhanced product performance. The capacity to examine numerous potential designs in minutes, rather than weeks, has given GM an edge in vehicle production.

5. Low Productivity and Inefficiency - Siemens is a German-based company that leverages technological innovation, featuring a digital enterprise suite fully underscored by AI-enabled tools, fostering machine data velocity while aggregating production data analysis, which eventually enabled the realisation of downtime reduction and efficiency increment. Among the principal challenges were unplanned downtime resulting from machinery failures, too high energy usage driving inefficiencies and food delivery mishaps against the sound supervision of raw material and logistics. To respond to these challenges, Siemens implemented AI for preventive maintenance, energy optimisation, and high-speed supply chain businesses. The predictive maintenance helped to prevent equipment from breaking down. AI sensors and machine learning models provide continuing monitoring of equipment health to anticipate breakdowns before they happen. For example, the Amberg electronics plant in Germany is monitored continuously by AI for performance, whereby operators are signalled ahead of possible shutdown threats, leading to an overhead cut of 30%, more time loss and production efficiency gains. Real-time AI-directed energy optimisation controlled operable conditions via dynamic AI modulations of power across its production base, supported the diffusion of the smart grid through Siemens, resulting in energy cost savings of 15% with a leaner production model. AI is also employed in demand forecasting, inventory optimisation, better logistics planning, and the improvement of logistics processes in general. With AI assistance, more competent forecasted demand reduced Siemens's overproduction and material shortages by 25%. Through immersive AI-based tech applications, Siemens changed the paradigm in manufacturing to combat wastefulness while improving productivity in line with sustainability objectives.

6. High Operational Cost- Czingier Vehicles, a Southern California automotive manufacturer, has effectively used artificial intelligence, alongside 3D printing, to change the way they manufacture machines with a keen focus on drastically bringing down operational costs.

Whenever automotive manufacturers design, a lot happens: elaborate assembly lines that consume significant amounts of materials, and labour costs equal to a large dent in the overall operational expenses, thus restricting flexibility in design and manufacturing.

AI-Driven Solutions

It is a design-and-manufacturing platform that brings together AI, 3D printing, and advanced materials science. The platform optimises the design for the performance along with the manufacturability of the automobile itself. The end result is lighter and tougher components, dependent on less material to complete production.

Outcomes:

- 1) **Cost Efficiency-** AI-driven designing assists in using up less raw material to make strategic development in the number of manual tasks needed; hence, lowered production costing is achieved.
- 2) **Performance Enhancement-** The design, which is optimized by the aforementioned factors, contributes to high vehicle performance, as seen with the Tour 21C setting multiple speed records.
- 3) **Scalability-** Flexible manufacturing systems are capable of creating distinct products economically with a lot to look ahead to today.

Conclusion: The use of artificial intelligence and 3D printing in Czingar Vehicles is a case study in applying newer technologies to improve operational effectiveness and reduce operational costs while improving critical product performance. The new approach simply serves to manage production more efficiently and also sets an innovative standard for the automotive industry.

7. Limited Innovation – Foxconn is the world's largest electronics manufacturer, but didn't enjoy much innovation: high labour costs, high defect rates, and overall inefficiency on the production line. Traditional systems could neither maintain quality nor be efficient in view of an ever-increasing customer demand. The organisation addressed some of these challenges with AI-driven automation, predictive maintenance, and smart quality control. Specifically, AI-powered robotic arms and computer vision systems were used: they allowed for increased precision in component assembly and reduced the defect rate by 30%. IoT sensors used for predictive maintenance reduced machine downtime by 20% and avoided unanticipated machine failures in advance. AI-enabled supply chain optimisation allowed for enhanced

production scheduling and resource allocation, consequently reducing operational costs. Top-notch AI involvement enabled Foxconn to enhance productivity and work efficiency while simultaneously cutting costs and improving product quality.

Conclusion

In conclusion, the future of Indian manufacturing appears extremely promising, where AI is a strong force for transformation. The advances in AI technologies, ranging from machine learning and robotics through predictive analytics to automation, now promise great change for manufacturing. With the adoption of AI, India has huge potential to improve its productivity and efficiency in the manufacturing sector, overcome supply chain challenges, reduce operational cost and improve the quality of its manufactured products. If India aspires to be a global manufacturing leader and a developed nation by 2047, then the adoption of AI will be inevitable for sustainable development, enhancing competitiveness and creating high-value jobs.

The Indian government, along with the MSME (Micro, Small and Medium Enterprises) sector, would have to take some appropriate actions toward the adoption of AI in India's manufacturing ecosystem. If India aims to play an important role in the ongoing AI revolution, the Indian government must implement policies to stimulate the adoption of AI, develop digital infrastructure, and encourage R&D for AI-specific applications. The following are some of the policy recommendations:

For disparate developments in AI in India's manufacturing sector and to reorient its path toward becoming an innovative and efficient global leader, the federal government will need to adopt a multi-faceted approach that encompasses R&D, skill enhancement, development of infrastructure, public-private partnerships, and regulatory processes. This will entail inducing R&D for AI applications in manufacturing challenges through grants, subsidised policies, and tax incentives, furthering innovation. While building such a consortium made up of universities, research institutes, and industrial players, the government must develop cutting-edge AI solutions that will be tailored toward addressing particular requirements among Indian manufacturers. These could span from predictive maintenance, supply chain optimisation, quality control, and automation of repetitive tasks, thereby enhancing productivity, reducing costs, and improving competitiveness in the world market. However, it is pressing to recognise that this blended application of AI within manufacturing will fundamentally hinge not so much

on further development of technology but on how prepared the people working in that manufacturing environment will be towards dealing with said technologies. Adoption of AI means a new job dealing with technology for people, which may finally draw attention to the necessity of reskilling and upskilling. The government should focus on establishing massive training programs for the workforce on skills relevant to AI, such as data analysis, strengthening machine learning, robotics, and human-machine collaboration. Such programs can be undertaken with the involvement of private sector actors, industry leaders, and educational institutions to ensure that the workforce, down to production workers and decision-makers, is trained to work alongside AI-enabled systems. An adequately trained workforce would contribute not only to seamless AI integration but also alleviate the risks of displacement by creating new job opportunities in AI-based manufacturing. To facilitate the scaling-up of AI undertakings across sectors of the economy, one should augment cooperation between the public and private sectors. Such short-term partnerships can develop AI adoptions for Micro, Small, and Medium Enterprises that contribute to more than 90% of total manufacturing output in India. Models for partnerships with MSMEs should be developed by the government to provide support in terms of supply chain, operations, intelligent product delivery, and selling, along with affordably available AI technologies, tools, and expertise, to facilitate modernisation and continuing competitiveness in domestic and international markets. These can include vast enterprises and AI startups encouraged to partner for a developmental assistance program for MSMEs, whereby they provide technical assistance, AI-based solutions, and mentorship to close the gap and increase the inclusiveness of the AI-powered manufacturing sector. Equally important for AI adoption is the establishment of a robust digital infrastructure that allows seamless AI implementation. Thus, government investment would require building AI-compatible infrastructure, including high-speed data lines, sophisticated data storage, and cloud computing systems for all parts of industry and agriculture to unleash the potential of artificial intelligence. Demanding greater support and resources for innovation, an AI Innovation Hub, and a Tech Cluster to be established in industrial areas, notably Tier-2 and Tier-3 cities, will take AI more broadly to small companies and start-ups in their pursuit of technological transformation. Such an enabling infrastructure would allow for open, extensive, and secure usage of AI applications for real-time analytics, industrial process automation, and smart manufacturing processes. The criticality of MSMEs to India's economy needs focused support measures for promoting AI adoption in this sector. The financial support provided by the government, such as through subsidised loans, grants, and tax benefits, will give MSMEs the confidence to invest in AI-

driven solutions catering to their precise operations. Also, affordable maintenance prediction tools and QA tools driven by AI should be engineered and put into the hands of small-scale manufacturers. To foster incubating AI centres and mentorship programs for MSMEs to develop innovations and promote the further uptake of AI manufacturing models in MSMEs. As AI technologies proliferate within the manufacturing sector, a regulatory framework will need to be defined to help address data privacy; cybersecurity and ethical issues must also be brought into discussion. The law must guarantee that the introduction of AI operations adheres to the present laws of the country about data protection, which can be supplemented by new laws that accentuate fairness, accountability, and transparency in AI-driven decision-making. Finally, the formulation of the responsible use guidelines for AI in manufacturing would call for ensuring that AI algorithms remain unprejudiced, render transparent results, and do not contravene ethical labour guidelines. In addition, attention must be given to dealing with cybersecurity issues because AI-led manufacturing creates an overwhelming amount of sensitive industrial data that has to be diligently preserved in view of ever-present threats of cyberattacks and data breaches.

Through a comprehensive and peremptory approach to the incorporation of AI in manufacturing, India could set its course to innovation, enhance production, and drive competitive advantages for its manufacturing base in a global marketplace. With excellent policies in place and massive infrastructure evolving around technology, a workforce willing to meet the challenges, and appropriate regulatory safeguards, India should forthwith align itself to become a global hub for AI-employed manufacturing, which will address the critical aspect of economic growth and sustainability.

The Indian Government has made several efforts to encourage AI adoption in the manufacturing industry, which includes publishing a National Strategy for Artificial Intelligence, encouraging AI startups under schemes like "India AI", encouraging the Production Linked Incentive (PLI) scheme for IT hardware, focusing on data infrastructure development, and giving priority to ethical AI guidelines to implement responsibly. The Finance Ministry has provided ₹2000 crore to the "India AI" mission for FY26. This is a mind-boggling hike of 1056% above the revised budgets in the 2024-25 budget that allocated ₹173 crore. The mission focuses on taking AI to core areas of the economy, like agriculture and health. Under the mission, the government facilitates access to subsidised graphics processing units (GPUs) for start-ups and researchers in the hopes of developing an AI model that can be

domesticated. This scheme was recently initiated for carrying out interdisciplinary research, creating innovative applications and scalable solutions to problems in the fields of agriculture, health, and sustainable cities with a perspective to enable the vision of 'Make AI in India and Make AI work for India'.

For India's manufacturing sector, especially MSMEs, the future is ripe with opportunity, but only if AI is integrated thoughtfully and strategically. By adopting these policy recommendations, India can transform its manufacturing landscape, driving innovation, economic growth, and sustainability in the process. The embrace of AI will not only elevate India's position in the global manufacturing arena but also empower its industries to remain resilient and competitive in an increasingly digital and automated world.

References

- Appinventiv. (n.d.). *How AI is transforming the manufacturing industry?* Retrieved February 17, 2025, from <https://appinventiv.com/blog/ai-in-manufacturing/>
- BrainBox AI. (n.d.). *Pharmaceutical campus uses AI to reduce carbon footprint.* Retrieved February 17, 2025, from <https://brainboxai.com/en/case-studies/pharmaceutical-campus-uses-ai-to-reduce-carbon-footprint>
- Digital Defynd. (n.d.). *AI use in manufacturing case studies.* Retrieved February 17, 2025, from <https://digitaldefynd.com/IQ/ai-use-in-manufacturing-case-studies/>
- Medium. (n.d.). *10 case studies on using AI to improve sustainability efforts.* Retrieved February 17, 2025, from <https://medium.com/@eddie.hc.tsui/10-case-studies-on-using-ai-to-improve-sustainability-efforts-92b0d3ee4ac5>
- Seraf AI. (n.d.). *Case studies in smart manufacturing: 5 AI success stories.* Retrieved February 17, 2025, from <https://serafai.com/blog/case-studies-in-smart-manufacturing-5-ai-success-stories/>
- ThirdEye Data. (n.d.). *Product quality control with AI for the manufacturing industry.* Retrieved February 17, 2025, from <https://thirdeyedata.ai/case-studies/product-quality-control-with-ai-for-the-manufacturing-industry/>
- Time. (n.d.). *Czinger's AI-designed, 3D-printed hypercar is rewriting the rules of auto manufacturing.* Retrieved February 17, 2025, from <https://time.com/7023380/czinger-3d-print-ai-sports-car/>
- Booth, H., & Johnson, V. B. a. D. (2024, September 23). How One Company is Using 3D Printing and AI to Make Sports Cars More Efficiently. *TIME*. https://time.com/7023380/czinger-3d-print-ai-sports-car/?utm_source=chatgpt.com)
- Think Topics | IBM. (n.d.). <https://www.ibm.com/think/topics/ai-in-manufacturing>[2]

3

Understanding Gender Differences in Emotional Regulation among Young Adults

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Abstract

The world we live in today is full of unexpected events, and being able to manage and comprehend them emotionally is very crucial. The highs and lows in one's life, whether of a school-going child or an elderly individual, can deeply affect their emotional stability and their mental health. The regulation of these emotions is very important for better psychological well-being and physical health, fostering relationships and enhancing overall productivity in one's performance. The concept of gender as a sociocultural factor can lead to different patterns in emotional regulation, and with the increased importance of ER, the results are still divergent in terms of variations in emotional regulation in relation to age and gender. The population of younger adults go through a tremendous period of transitions from educational shift to attachment styles and career planning to the need for independence. Hence, this research paper aims to assess the differences in emotional regulation of younger adults in relation to gender through a quantitative design method. The study involved 191 participants, comprising 91 males and 100 females from various demographics. The participants were aged between 18-30 years and completed the Emotional Regulation Questionnaire. The results indicated no statistically significant gender differences in emotional regulation in males and females, breaking the past-based stereotypes ($p= 0.978$). In cognitive appraisal as in the context to previous studies, females showed a slightly higher tendency ($M= 27.86 < 28.63$) and males displayed slightly greater expressive suppression ($M=17.47 > 16.67$). The lack of significant correlation was found between cognitive reappraisal and emotional suppression in both genders ($r= 0.055$ & $r= 0.144$). The study reflected gender-based patterns, but especially revolved around younger adults, for the need to understand this critical and sensitive developmental stage. This study will contribute to a deeper understanding of gender dynamics in emotional regulation and inform about improving mental health outcomes of younger adults that goes beyond gender factors.

Keywords: Emotional regulation, Psychological well-being, Younger adults, Mental health, Gender difference, Cognitive appraisal

Understanding Emotional Regulation and Biological Basis

Emotional regulation has gained popularity over the last few decades in a variety of psychological sub-disciplines. “Emotion regulation” is a term referring to an individual’s capacity to manage and navigate emotional experiences in a constructive and adaptive way. Interest in emotional regulation has increased recently as it draws on a number of themes in the study of emotional development. (Thompson, 1993). It can occur at any point during an emotional reacting using methods that are either conscious or unconscious and can be described as "the internal and external mechanisms in charge of tracking, assessing, and altering emotional responses, particularly their temporal and intense aspects, to achieve one's objectives" (Thompson, 1994).

The process model of emotion regulation is one helpful organisational structure (Gross, 2015). At the first level of this, emotion generation is defined in a sequential manner. model as having relevant experiences, focusing on significant characteristics of those circumstances, assessing the circumstances in view of ongoing objectives, and displaying behavioural, physiological, and/or sensory responses. Emotional regulation is essential for mental health, social functioning, and general well-being because it helps people deal with difficulties, keep their moods steady, and maintain wholesome relationships.

The neural mechanisms underlying emotional regulation involve key brain regions, including the prefrontal cortex (PFC), amygdala, anterior cingulate cortex (ACC), and insula. For cognitive control and executive functions like cognitive reappraisal, which entails reinterpreting a situation to change its emotional impact—the prefrontal cortex, especially the dorsolateral and ventromedial areas, is essential.

In contrast, the amygdala processes emotions, particularly fear and threat, and emotional regulation frequently entails regulating its activity. It's critical to realise that controlling excessive emotional reactivity in the amygdala usually necessitates top-down control from the prefrontal cortex. Disorders like anxiety, depression, and borderline personality disorder are frequently associated with emotional dysregulation and disruptions in these circuits, especially in the connectivity between the PFC and amygdala.

Genetic factors are the primary determinants of individual differences in emotional regulation. Studies have revealed genetic variations affecting the neurotransmitter systems that control emotions, including the oxytocin, dopamine, and serotonin pathways. Understanding the

causes of individual differences in emotional regulation and the persistence of psychological disorders is made easier by these genetic variances.

Theoretical perspectives

Gross' Model for Emotion Regulation explains that it involves both the conscious and unconscious strategies used to enhance, sustain or reduce different aspects of an emotional response (Gross, 2001). According to this definition, emotion up-regulation occurs when an emotional response's component parts increase, whereas down-regulation occurs when these components decrease. According to this model, humans can influence their level of emotional response for a particular emotion by using antecedent-focused strategies, which are used to prepare for response tendencies before they are fully activated, and response-focused strategies, which are used to activate the actual emotional response, once an emotion is already underway.

Four different types of antecedent-focused emotion regulation strategies have been suggested in this model, which include:

Situation selection: A person chooses to be in a situation that matches the emotional response level the person wants to have for a certain emotion.

Situation modification: A person modifies an existing situation so as to obtain a different level of emotion.

Attentional deployment: Shifting your attention to a certain aspect.

Cognitive change: Selecting a cognitive meaning to an event

In addition to these techniques, there is a fifth category of emotional regulation techniques: response modulation. This type of strategy is response-focused and aims to influence how response tendencies develop into behavioural responses.

Control Theory of Emotion Regulation was introduced by Carver and Scheier in 1981. One of the main tenets of control theory is that abstract goals at a higher level establish criteria for actions at lower levels of cognition. The model incorporates two levels of control. An input state is tracked and contrasted with the standard at each level. An effector that aims to alter the input state is triggered when there is a difference between the two. Until the disparity is zero, the procedure is repeated. Control at the next level up is changed to meet the standard if behaviour at a low level is not adequate for the task at hand. The division of the control layers allows the lower control loops (emotion control) to regulate emotion in order to satisfy the requirements set by the higher loops.

The higher loops' standards are then managed to protect resources. The model's two control layers are further separated into two groups: displayed emotion state and internal emotion state. Both the target for the desired intensity of emotion and the level of regulated emotion experienced are determined by the internal states. The intensity of regulated emotion that is expressed and the standard for the appropriate intensity are determined by the states that are displayed.

Strategies of Emotional Regulation

Emotional regulation strategies can have varied impacts on an individual's experiences, cognitive processes, social interactions and overall well-being (Gross, 2002; Phillips et al., 2006; Rubin et al., 2009). Researchers have identified five key strategies for emotional regulation: expressive suppression, situation modification, situation selection, attention deployment, and cognitive reappraisal (Gross, 1998 & 2002).

Among these, the two most widely studied techniques are cognitive reappraisal, which is antecedent-focused and expressive suppression, which is response-focused (Zaehringer et al., 2020; McRae and Gross, 2020).

Cognitive reappraisal is an antecedent-focused emotion regulation technique that takes place early in the emotional experience. This tactic effectively alters emotional experiences through cognitive process modulation, which includes reinterpreting emotional events (Gross, 1998a). Detachment, an objective viewpoint, and more constructive reinterpretation, distancing, or fictional reappraisal are all part of it. Downregulation, as used in cognitive reappraisal, is the process of reinterpreting a situation to lessen the intensity of negative emotions. Conversely, upregulation is the deliberate amplification of positive emotions and the reinterpretation of a situation to increase positive emotions.

Conversely, expressive suppression is a response-focused emotion regulation technique that takes place in the latter stages of an emotion. It is used to inhibit emotional expression by suppressing emotional activities (like facial expressions) that are occurring in order to regulate emotional experience. While reappraisal is generally healthier and has a longer-lasting effect on emotion regulation, suppression aids in emotion regulation more quickly.

In contrast to suppression, research indicates that the use of reappraisal has produced longer-lasting positive outcomes like psychological well-being and increased positive affect. As a

result, depending on the situation and when they are used, both approaches may be beneficial. People from individualistic and collectivistic cultural backgrounds are also said to differ from one another (Diaz & Eisenberg, 2015).

In particular, individuals from collectivist cultures appear to use suppression rather than reappraisal because maintaining "group" harmony discourages the expression of individual feelings (Matsumoto, Yoo, & Nakagawa, 2008). Individualistic cultures, on the other hand, encourage emotional expression because they value autonomy and individual harmony, which causes people to reevaluate their feelings (Matsumoto, 2006).

Psychosocial Importance

Our psychosocial and physical well-being is greatly influenced by the emotions we experience and express; for example, they may help us achieve our goals, improve our relationships with others, and direct our behaviour to better promote health. Emotions are not always adaptive and functional, though. They could, for instance, force us to make a risky or socially inappropriate decision or sever a crucial interpersonal relationship. To effectively respond to environmental demands in these situations, emotional regulation is required (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Gross, 2007; McLaughlin, Hatzenbuehler, Mennin, & Nolen-Hoeksema, 2011).

Inappropriate or challenging regulation, for example, can result in interpersonal challenges, behavioural and health issues, more prolonged or severe negative affect (such as anger or anxiety), and decreased resilience to stressful situations (Aldao et al., 2010, 2015; Gross, 2007; Moore, Zoellner, & Mollenholt, 2008; Webb, Miles, & Sheeran, 2012).

Coping and emotion regulation techniques can be enhanced by perceived social support, which is the conviction that one's friends, family, or community are there to support them. Although the relationship between various parenting styles has not been investigated, parenting styles during childhood can have a significant impact on emotion-regulation strategies. In general, improved emotional regulation and resilience can result from social anxiety and positive social support (Gross et al., 2012).

Emotional regulation refers to the ability to manage and control one's emotions, which plays a crucial role in influencing behaviours. Examples include reframing challenging situations to reduce feelings of anger and anxiety, suppressing visible signs of fear or sadness, or focusing

on reasons to feel calm and content. Difficulties in emotional regulation are often associated with various mental health conditions such as depression, borderline personality disorder, substance abuse disorders, eating disorders and somatoform disorders. These challenges can hinder effective coping mechanisms and contribute to the development of psychopathological symptoms (Kim et al., 2024).

Emotion regulation is crucial for developing adaptive cognitive style, decision-making skills, and behavioural intentions in response to social and situational demands, as numerous empirical studies have shown. These factors ultimately affect an individual's well-being (Kraiss et al., 2020). The positive effects of emotion regulation techniques linked to solution-focused coping and improved psychological well-being have also been demonstrated in earlier research. Conversely, maladaptive behaviours and psychological distress have been closely linked to dysregulation (Bradley et al., 2011; Verzeletti et al., 2016).

Developmental Aspects of ER

Emotional instability and cognitive impairment are common in young adults, which can disrupt daily life and result in psychopathology. They are more likely to investigate how emotions are regulated and to use less passive tactics like avoidance and passive dependence. Young adults have more frequent and intense emotions than older people, and emotional regulation is crucial for psychological health and well-being. Individual variations in mental health and adjustment during times of elevated risk can be better understood by comprehending emotional regulation during this time.

The development of emotion regulation is thought to occur gradually, with late adolescence marking a particularly mature stage (Gross, 2015; McRae et al., 2012; Riediger & Klipker, 2014). A study that used fMRI scans and taught older kids, teens, and young adults to use cognitive reappraisal discovered that reappraisal skills increased with age (McRae et al., 2012). Early adolescents reported using fewer adaptive cognitive-emotion regulation techniques (like positive reappraisal) than late adolescents, who in turn reported using fewer than adults, according to a study of people aged 12 to 97 (Garnefski & Kraaij, 2006).

Research has shown that first-year college students tend to rely more on suppression during the period from 2 months before arriving on campus to shortly after settling in (Srivastava et al., 2009). However, Kneeland & Dovidio (2020) observed the shift by the end of the first semester, with suppression decreasing and reappraisal becoming more common. Another study, which

focused on students aged 11 to 22 reported modest improvements in overall emotional regulation abilities (Hardy et al., 2020). As a result, developing healthy emotional regulation strategies is critical for achieving positive life outcomes, overcoming challenges, and improving interpersonal relationships and health outcomes.

Factors Affecting ER

Affective Factors

An individual's cognitive load is increased by high emotional intensity, which puts pressure on the cognitive resources needed for emotion regulation. When emotional intensity increases during emotion regulation, people's attentional breadth narrows, leading them to choose distraction over reappraisal (Milyavsky M, Webber D, Fernandez JR, et al., 2019). People employ various cognitive reappraisal techniques to control various emotions, according to Vishkin et al. (2020). For example, people prefer to use an acceptance reappraisal technique to control sadness. Furthermore, people tend to choose cognitive reappraisal more frequently when regulating anger, and distraction strategies more frequently when regulating disgusting emotions (Young G, Suri G., 2020).

Cognitive Factors

Even in situations with comparable intensities, emotional stimuli can differ in their reappraisal affordances, or the innate chances for semantic reinterpretation. Distraction was more likely to be chosen by those with lower reappraisal affordance, while cognitive reappraisal was more likely to be chosen by those with higher affordance. (Forestman JJ, Freitas AL, 2021; Young G, Suri G, 2020; Suri G et al., 2018) A person's choice of emotion regulation is also impacted by how much work they believe it will take to try regulation. Reducing cognitive effort increased the likelihood that subjects would select cognitive reappraisal, according to Milyavsky et al. (Milyavsky M, Webber D, Fernandez JR, et al., 2019).

Motivational Factors

The effects of goal motivation on emotion regulation choices have been studied from a variety of goal perspectives, including situational/instrumental goals (Tamir M, Ford BQ, 2012), directional goals (Millgram et al., 2019), and temporal goals (long-term or short-term regulation goals). When attempting to down-regulate emotions, people are more likely to choose distraction, and when attempting to up-regulate emotions, they are more likely to choose rumination (Millgram et al., 2019). Additionally, it has been discovered that people

prefer feelings that enable them to accomplish a particular objective, even if those feelings result in negative feelings (Tamir M, Ford BQ, 2012; Tamir M, Ford BQ, Gilliam M, 2013; Tamir M, Ford BQ, 2012).

Individual Differences

Individual differences, including age, gender, and personality traits, all have an impact on how people choose to regulate their emotions. Some examples of these differences are as follows:

Age: As people age, they use cognitive reappraisal more frequently while using expressive inhibition less frequently. Gross JJ, John OP, 2004

Personality: Cognitive reappraisal was more frequently used by people who exhibited extroverted personality traits (Gross JJ, John OP, 2003).

Psychological Disorder: People with posttraumatic stress disorder (Hannan SM, Orcutt HK, 2020), borderline personality disorder (Sauer C et al., 2016), internet addiction (Yan XY et al., 2022), and bipolar disorder (Hay AC, Sheppes G, Gross JJ, 2015) selected cognitive reappraisal less frequently than the overall population.

Gender Variations in Emotional Regulation

Kaur et al. (2022) discovered that patients with various illnesses use different emotional regulation techniques depending on their gender. Whereas women exhibited less emotional clarity, men struggled more to accept emotions and control their impulses. These variations could account for the disparities in the prevalence of mental disorders and their clinical manifestations between the sexes. Knowing these tactics may make it easier to start gender-specific interventions to stop the progression of illness and maladaptive behaviours.

Preston et al. (2021) used a cross-sectional study with OLS regression and moderation analysis to investigate the moderating role of gender in cognitive reappraisal, emotional suppression, and depressive and anxiety symptoms. The findings indicated that women use cognitive reappraisal (CR) more frequently than men do, and that women's symptoms of anxiety and depression are inversely correlated with CR use. Although ES is more common in men than in women, it has nothing to do with symptoms of anxiety or depression.

According to Brody's (1985) analysis of gender differences in emotional development, boys and girls display varying degrees of emotional expression and recognition skills. Boys are becoming less able to express and attribute most emotions, while girls are becoming less able to express and identify emotions that are socially unacceptable, like anger. Different

socialisation processes, innate temperamental differences, or social pressures could be the cause of these variations.

A study by Rogier et al. (2017) on 380 people living in a community revealed gender differences in aggression and emotional suppression. It was discovered that emotional suppression was more significantly associated with psychological distress in women. On aggression measures, however, men demonstrated significant interaction effects between reappraisal and suppression, confirming gender differences in emotion regulation and the significance of adaptability in emotional regulation techniques.

Perchtold et al. (2019) examined gender differences in well-being and emotion regulation in another study. It was discovered that the fundamental abilities of men and women to produce cognitive reappraisals under challenging circumstances are comparable. However, fewer depressive experiences were predicted by men's higher cognitive reappraisal capacity. The results imply that a complex interplay of fundamental skills, routines, efficacy beliefs, and additional emotion regulation techniques may determine women's advantages for well-being.

According to Duarte et al. (2015), depression is a common psychological disorder affecting teenagers. Gender moderates the association between positive reappraisal and depressive symptoms, according to a study of 319 teenagers, highlighting the significance of boosting positive reappraisal in the face of adversity. According to the findings, girls exhibited more depressive symptoms than boys. Maladaptive behaviours and problems regulating emotions are associated with gender differences in depressive symptoms.

Wu et al. (2024) investigated the relationships among expressive suppression, life satisfaction, and cognitive reappraisal through a meta-analysis. The findings indicated that, in contrast to expression suppression, cognitive reappraisal had a moderately positive correlation with life satisfaction. Regional cultural values moderated the relationship, but neither gender nor age had an impact. There was no significant correlation between Eastern and Western cultural values, but there was a significant negative correlation.

McRae et al. (2008) use functional magnetic resonance imaging to investigate how gender differs in emotion regulation. Participants were instructed to down-regulate their emotional reactions to negatively valenced images by using a cognitive emotion regulation technique called reappraisal. In terms of behaviour, the declines in negative emotion experience were comparable for men and women. Gender differences were found in neural regions, though,

with men exhibiting larger decreases in the amygdala and ventral striatal region and smaller increases in prefrontal regions linked to reappraisal.

Research Objectives

The following research objectives were made for the present study-

- 1) To examine the gender differences in emotional regulation in male and female young adults
- 2) To examine gender differences in the use of cognitive reappraisal as an emotional regulation strategy among young adults
- 3) To examine gender differences in the use of emotional suppression as an emotional regulation strategy among young adults

Research Hypotheses

With respect to the framed results objectives, the following research hypotheses were constructed for the present study-

H₀- There will be no significant difference between emotional regulation scores of male and female young adults.

H₁- There are no gender differences in the use of cognitive reappraisal as an emotional regulation strategy among males and females.

H₂- There are no gender differences in the use of emotional suppression as an emotional regulation strategy among males and females.

Method

Design of Research

In the present research study, a quantitative research design has been used, where data is collected in numerical or quantitative form for analysis as quantitative studies rely on numerical data to identify patterns, differences and relationships, for which closed-ended questions are used to collect responses. In addition to this, between-the-group design was incorporated, where group differences based on certain criteria of interest of researcher (gender) are compared and studied, has been used in present research to assess the differences in emotional regulation of younger adults in relation to both the genders (male and female) through a quantitative design method.

Sample

In the present research, the purposive sampling technique was incorporated, which is a non-probability sampling technique where the participants, groups, or data points are selected based on specific characteristics or criteria relevant to the study to ensure gender representation. A convenience sampling technique was used, where the selection of participants was based on convenience and proximity. The stratified-random sampling technique was also incorporated, which is a type of probability sampling technique where the population is divided into various strata based on the purpose of the research (gender). Here, the two strata were males and females and data was collected from 191 participants, consisting of 91 males and 100 females between the age range of 18 to 30.

Material Used

In the present research following materials were used: Emotional Regulation Questionnaire (ERQ), Google form (replica of ERQ), SPSS software and stationery.

Variables

Independent variable – Gender (male and female)

Dependent variable – Emotional regulation

Description of Tool

In the present study, a self-report tool, the Emotional Regulation Questionnaire, developed by Gross & John in 2003, was used. ERQ is based on the process model of emotion regulation given by Gross (1998). ERQ is used to evaluate individual differences in emotional regulation which included 10 items designed to measure 2 specific strategies- cognitive reappraisal (6 items) and expressive suppression (4 items). In ERQ, items are answered on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree).

The ERQ scale scores have consistently shown reliable internal consistency, with Cronbach's α exceeding .70, across various sample groups and cultural contexts. This has been supported by research studies of Balzarotti et al. (2010), Cabello et al. (2013), English and John (2013), Gross and John (2003), Spaapen et al. (2014), and Wiltink et al. (2011). The factor analysis consistently confirms the two-factor structure of reappraisal and suppression, with high factor loadings typically ranging from 0.70 to 0.90 construct validity.

Data Analysis

The data collected was analysed using SPSS, and foremost, descriptive statistics were employed to provide an overview of the dataset, including measures of central tendency and variability. Specifically, we calculated the mean and standard deviation for the cognitive reappraisal and expressive suppression subscales of ERQ. This helped us better understand the general trends in emotional regulation strategies among the participants.

Further, the t-test was used to compare the means of male and female participants to explore if there were significant differences in their emotional regulation strategies. In this study, the t-test assessed whether the differences in mean scores of both strategies between male and female participants were meaningful, providing insights into gender-based differences in emotional regulation strategies. Additionally, Pearson's Correlation was used to examine the strength and direction of the relationship between ER strategies.

Procedure

After reviewing literature on emotional regulation, the need to focus on younger adults in terms of understanding their emotional regulation was identified. In addition to this, a research gap was identified, and further inquisitiveness to understand differences in emotional regulation of younger adults, particularly between males and females, led to the framing of the present research aim. Through rigorous group discussion appropriate tool to accomplish the aim of the research was selected, ensuring that it can quantitatively support the findings of the research. Hence, the Emotional Regulation Questionnaire (ERQ) was chosen.

Using items of ERQ, an exact replica of it on Google Form was made, consisting of all items of ERQ that incorporated a 7- 7-point Likert scale. It was ensured that consent of all participants was taken within a Google Form, and preliminary details, particularly those of concern in the present research, were collected from participants, including demographic information.

The standardised instructions were given to all participants through the form to participants: "We would like to ask you a few questions about your emotional experiences, focusing on how you manage and regulate emotions. These questions address two key areas: your internal emotional experiences, that how you feel internally and your emotional expressions, that how you convey those emotions through speech or gestures. While some questions may appear similar, each touches on different aspects. For each item, please answer using the following

scale: 1(strongly disagree), 2 (somewhat disagree), 3 (disagree), 4 (neutral), 5 (agree), 6 (somewhat agree), 7 (strongly agree).”

Scoring

The Emotional Regulation Questionnaire was used for the present research study to measure individual differences in emotional regulation strategies- cognitive reappraisal and expressive suppression in relation to gender.

The scores for emotional regulation strategies were calculated separately, where cognitive reappraisal was calculated by summing the scores for statements 1, 3, 5, 7, 8 and 10 and expressive suppression was calculated by summing the scores of statements 2, 4, 6 and 9. No items were scored in a reverse manner. A total score for emotional regulation was also calculated by adding all the scores of the questionnaire.

Results

The following table 1 shows the individual scores in relation to gender on the emotional regulation questionnaire using tools of descriptive statistics-

<i>Table 1: Descriptive Statistics</i>				
Gender	Males		Females	
Sample	n1= 91		n2= 100	
	M	SD	M	SD
Cognitive Reappraisal	27.85	5.54	28.63	4.92
Emotional Suppression	17.47	5.23	16.67	4.58
Total ER Score	45.33	7.83	45.3	7.19

Table 1 depicts the results of males and females on emotional regulation questionnaire with the use of descriptive statistics, where the variables measured were cognitive reappraisal, emotional suppression and total emotional regulation score. It was found that males scored a total mean score of 45.33 (SD= 7.83). Males obtained a mean score of 27.85 (SD= 5.54) in cognitive reappraisal as an emotional regulation strategy, whereas in emotional suppression, they obtained a mean score of 17.47 (SD= 5.23).

Whereby in females, the total emotional regulation mean score was obtained as 45.3 (SD= 7.19). Females obtained a mean score of 28.63 in cognitive reappraisal (SD= 4.92), whereas in emotional suppression, females obtained a mean score of 16 .67 (SD= 4.58).

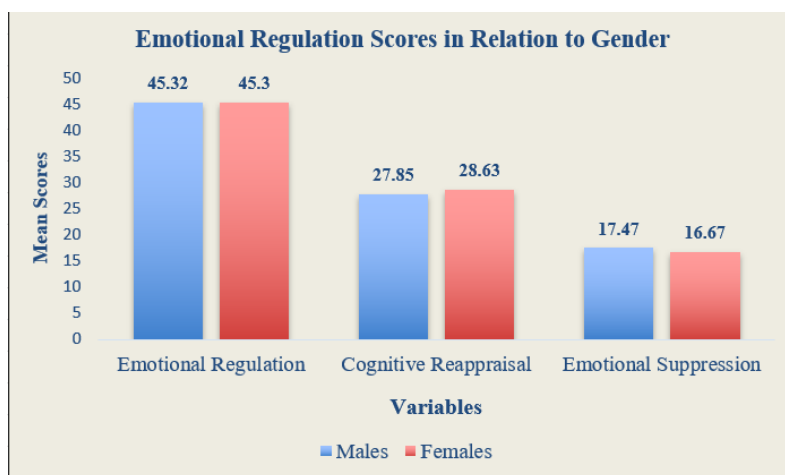
It can be said that both genders exhibit similar levels of cognitive reappraisal, with females slightly higher on average, as $27.85 < 28.63$. In terms of emotional suppression as an emotional regulation strategy, it was found that males use this strategy marginally more than females, as $17.47 > 16.67$. In relation to the total emotional regulation score, both genders have nearly identical overall scores as 45.33 and 45.3 for males and females, respectively.

The following table 2 shows the descriptive statistic summary on the emotional regulation strategies, depicting mean and standard deviation scores-

Table 2: Descriptive Statistics			
	N	Mean	SD
Gender	191	1.52	0.501
Cognitive Appraisal	191	28.26	5.23
Emotional Suppression	191	17.05	4.9
Total	191	45.31	7.48
Age	191	19.88	2

In accordance with the results of Table 02 depicting descriptive statistics summary, the overall mean score of emotional regulation for a total of 191 participants was 45.31 (SD= 7.48), indicating moderate emotional regulation capability among both genders. The average mean score of cognitive reappraisal came out to be 28.26 (SD= 5.23), indicating moderate use of cognitive reappraisal as an emotional regulation strategy across participants. Whereas, the average mean score of emotional suppression was 17.05 (SD= 4.9), reflecting a lower reliance of emotional suppression as an emotional regulation strategy among the participants.

Graph 1: Gender Differences in Emotional Regulation Scores-



Hence, according to the summary from descriptive statistics as depicted through Graph 1, depicting the mean scores on emotional regulation with relation to both genders, it is concluded that there were minimal gender differences found across emotional regulation strategies in both genders, as males and females regulate emotions in largely similar and identical ways.

The following table 3 shows the individual scores in relation to gender on the emotional regulation questionnaire using an independent sample t-test.

<i>Table 3: Independent Sample t-Test</i>						
	Gender	N	M	SD	t	p
Age	Male	91	19.96	2.087	0.468	0.64
	Female	100	19.82	1.93		
Cognitive Reappraisal	Male	91	27.86	5.545	-1.02	0.309
	Female	100	28.63	4.927		
Emotional Suppression	Male	91	17.47	5.233	1.129	0.26
	Female	100	16.67	4.588		
Total	Male	91	45.33	7.83	0.027	0.978
	Female	100	45.3	7.199		

An independent sample t-test was conducted to find out gender differences in emotional regulation in terms of age, emotional regulation strategies as cognitive reappraisal and emotional suppression, to find whether any significant differences exist between them.

As per Table 3, with respect to age, there was no significant difference in the age distribution of male and female participants, as the mean score obtained for males was 19.96 and for females was 19.82. The t-statistic was obtained as $t(189) = 0.468$ and $p = 0.640$. It ensured that age was not a confounding variable that influenced emotional regulation.

In accordance with cognitive reappraisal, males obtained a mean score of 27.86, whereas females obtained that of 28.63, with the t-statistic value as $t(189) = -1.020$ and $p = 0.309$. It could be interpreted that the difference in the scores of males and females with respect to cognitive reappraisal is not statistically significant, which suggests that both genders employ cognitive reappraisal as an emotional regulation strategy at a very similar level.

In accordance with emotional suppression, males obtained a mean score of 17.47, whereas females obtained that of 16.67, with the t-statistic value as $t(189) = 1.129$ and $p = 0.260$. It could be interpreted that there is no significant difference in emotional suppression scores of both genders and both equally use it as an emotional regulation strategy, with males showing a slighter higher mean score, but non-significant as compared to females.

It was found that the total emotional regulation mean score obtained by males was 45.33 and that of females was 45.30, with the t-statistic $t(189) = 0.027$ and $p = 0.978$. Hence, it could be concluded that there was no significant difference in overall emotional regulation scores between both genders as males and females, indicating that both exhibit similar overall emotional regulation capacities. This could imply that emotional regulation strategies are not heavily influenced by gender in younger adults, where there is a balanced use of reappraisal and suppression as emotional regulation strategies.

The following table 4 shows the correlation coefficients in relation to gender in the emotional regulation strategies using the Pearson product-moment correlation method-

<i>Table 4: Pearson's Correlation Coefficients</i>			
Gender	Cognitive Reappraisal	Emotional Suppression	Total
Male	0.745 ($p < 0.001$)	0.707 ($p < 0.001$)	0.055 ($p = 0.606$)
Female	0.776 ($p < 0.001$)	0.736 ($p < 0.001$)	0.144 ($p = 0.154$)

Pearson product-moment correlation was used to examine the relationships between variables as cognitive reappraisal and total emotional regulation, emotional suppression and total emotional regulation and cognitive reappraisal and emotional suppression. It was found, as shown in Table 4, that the correlation coefficient between cognitive reappraisal and total emotional regulation for males was $r = 0.745$, $p < 0.001$. It can be concluded that there was a strong positive correlation between cognitive reappraisal associated with higher total emotional regulation scores, which could be understood as being a significant contributor to overall emotional regulation in males. In case of females, the correlation between cognitive reappraisal and total emotional regulation was $r = 0.776$, $p < 0.001$. So, it is found that there was a very strong positive correlation between cognitive reappraisal and emotional regulation in females, which can be said to be the most significant contributor to overall emotional regulation.

It is also found that the correlation between emotional suppression and total emotional regulation in males was $r = 0.707$, $p < 0.001$. It could be interpreted that there was a strong positive correlation between them, and it can be said that emotional suppression was also a great contributor to total emotional regulation in males, but it was comparatively slightly weaker than that of cognitive reappraisal as an emotional regulation strategy. In case of females, the correlation between emotional suppression and total emotional regulation was $r = 0.736$, $p < 0.001$. It could be stated that there was a strong positive correlation between both

the variables, and similar to males, emotional suppression has a slightly weaker influence than that of cognitive reappraisal on female younger adults.

The correlation coefficient obtained between cognitive appraisal and emotional suppression as emotional regulation strategies in males was $r = 0.055$ ($p = 0.606$). It is interpreted that there was a very weak and non-significant correlation between cognitive reappraisal and emotional suppression in males, that suggests that males use these strategies separately. Whereas in females, the correlation coefficient obtained between the emotional regulation strategies was $r = 0.144$ ($p = 0.154$), indicating a weak, non-significant correlation again that are relatively independent for females, as is similar to males.

Hence, it can be articulated that cognitive reappraisal was a dominantly used emotional regulation strategy that shows the strongest positive correlation with total emotional regulation, while emotional suppression has a slightly weaker relationship as a secondary strategy. While both genders show similar trends, females have slightly stronger correlations for both emotional strategies. There was a lack of significant correlation found between cognitive reappraisal and emotional suppression in both genders, hence suggesting that both strategies are used separately and not in conjunction.

Discussion

The present study investigates gender differences in emotional regulation among young adults aged 18 to 30, focusing on both cognitive and emotional regulation strategies using a quantitative design, where the results failed to reject the framed hypotheses. This means the null hypothesis was not rejected as there were no statistically significant gender differences found in emotional regulation scores, in either expressive suppression or cognitive reappraisal in male and female young adults. Also, H_1 and H_2 , got failed to reject as there were no gender differences found in the cognitive reappraisal scores and emotional suppression scores as emotional regulation strategies in both male and female young adults, which were elaborately confirmed with the help of the t-Test results. These findings are consistent with the emerging body of research challenging long-held gender-based assumptions about emotional regulation.

Unlike previous research, which often emphasised stereotypes or relied on self-reported data, our breakthrough findings revealed there were no statistically significant gender differences in emotional regulation abilities in younger adults in relation to males and females. This

challenges traditional narratives and offers a fresh perspective on the role of gender in emotional processes. Earlier studies have frequently perpetuated gendered assumptions about emotional regulation. Gross and John (2003) explored emotional suppression and reappraisal through self-reports, concluding that women suppress emotions less than men due to societal norms promoting female expressiveness. However, self-reports are susceptible to cultural biases and expectations, which can skew results. In contrast, our study employed objective measures of cognitive ability (CA) and emotional stability (ES), revealing only minor gender differences that lacked statistical significance.

Similarly, McRae et al. (2008) used fMRI to investigate neural mechanisms underlying emotional regulation, finding that men typically exhibit more automatic regulation processes, while women rely on effortful cognitive strategies. Despite these differences in neural pathways, both genders were equally effective in regulating emotions. This aligns with our findings, where males and females showed comparable overall emotional regulation abilities, underscoring the idea that effectiveness is independent of the strategies used. Cultural context is another critical factor influencing emotional regulation.

Hofstede et al. (1980) emphasised that collectivist cultures often encourage emotional suppression as a regulation strategy, affecting both genders equally. Our study, conducted with a likely diverse sample, reflects this cultural influence, providing a broader understanding of emotional regulation beyond Western-dominated research.

This contrasts with Nolen-Hoeksema (2012), who reported that women tend to engage more in rumination (a maladaptive strategy) largely due to Western societal pressures. Focusing on the age range of 18 to 30, our research contributes new insights into emotional regulation during early adulthood. Roberts et al. (2006) suggested that gender differences in emotional regulation are more pronounced during adolescence, with females exhibiting greater emotional awareness. By examining young adults, our study captures a period when emotional regulation strategies stabilise, demonstrating gender similarities rather than emphasising differences during earlier developmental stages. One of the groundbreaking aspects of this research is its exploration of within-gender correlations. Thompson et al. (2011) emphasised between-gender differences, such as women's higher emotional expressiveness. In contrast, our study highlights that cognitive ability (CA) strongly correlates with overall emotional regulation (Total) within both genders. This indicates that individual traits, rather than gender, play a more significant role in shaping emotional regulation capabilities.

Our findings align with Zimmerman and Iwanski (2014), who concluded that emotional regulation is more influenced by situational and contextual factors than inherent gender differences. By integrating cognitive and emotional components into a composite measure, we provide a holistic view of emotional regulation that prioritises complexity over reductive gender comparisons. This study sets itself apart by challenging entrenched stereotypes about gender and emotional regulation, using an objective, data-driven methodology to explore these dynamics among young adults aged 18 to 30. Unlike prior research that emphasised societal norms or relied heavily on self-reported data, our findings reveal the absence of significant gender differences, suggesting that emotional regulation is shaped more by individual traits and contextual factors than by gender. This work reframes the discourse, paving the way for future research that adopts more inclusive and nuanced approaches to studying emotional regulation.

Conclusion

The present paper aims to understand the gender differences in emotional regulation among young adults. A quantitative research design was used wherein data from 191 participants (F=100, M=91) was recorded. The Emotional Regulation Questionnaire, developed by Gross and John (2003), measures individual differences in the habitual use of two emotion regulation strategies: cognitive reappraisal and expressive suppression. Statistical analysis of data was done using SPSS. Through descriptive statistics, it was found that there were minimal gender differences across emotional regulation strategies in both genders. The independent samples t-test indicates no statistically significant differences between males and females for cognitive ability and emotional stability. In terms of correlation, among males, CA and Total have a strong positive correlation, indicating that cognitive ability is closely associated with total emotional regulation. A similar strong correlation exists for females. The findings of the present study suggest that while there are small variations in mean scores, none of these differences are statistically significant. This suggests that gender does not significantly influence the emotional regulation abilities measured here.

The findings of this study challenge traditional gender-based assumptions, promoting a more equitable understanding of emotional regulation abilities across genders, emphasising the importance of focusing on individual traits and cultural contexts. By shifting the paradigm from stereotypes to evidence-based insights, this research paves the way for tailored mental health interventions to address individual traits rather than relying on gender-based assumptions,

culturally sensitive approaches, and policies that better support young adults during a critical developmental stage as insights into the 18–30 age group highlight a critical period for stabilizing emotional regulation, guiding educational and workplace policies to support emotional well-being during this life stage. The research paradigm shift encourages future studies to explore factors beyond gender, such as personality and environment, for a deeper understanding of emotional regulation.

Limitations

Emotional regulation is often measured by self-reported questionnaires, making it prone to bias of social desirability, and participants may underreport or overreport their regulation abilities based on their understanding of the topic. The time constraints resulted to a limited sample size for the study. The findings of the study may not be universally applied to all the younger adults due to cultural, environmental or socioeconomic factors influencing the emotional regulation differently.

References

- Altemus, M. (2006). Sex differences in depression and anxiety disorders: Potential biological determinants. *Hormones and Behavior*, 50, 534-538.
- Balzarotti, S., Gross, J. J., & John, O. P. (2010). An Italian adaptation of the emotion regulation questionnaire. *European Journal of Psychological Assessment*, 26, 61–67
- Brody, L. R. (1985). Gender differences in emotional development: A review of theories and research. *Journal of Personality*, 53(2), 102–149. <https://doi.org/10.1111/j.1467-6494.1985.tb00361.x>
- Cabello, R., Salguero, J. M., Fernández-Berrocal, P., & Gross, J. J. (2013). A Spanish adaptation of the emotion regulation questionnaire. *European Journal of Psychological Assessment*, 29, 234-240
- Cameron, D., Totterdell, P., Holman, D. Et al. (1 more author) (2009) Control theory model of emotion regulation: A dynamic model of emotion. In: Proceedings of, 10 th IFIP Working conference on Virtual Enterprises, 07-09 Oct 2009, Thessaloniki, Greece. .
- Chee, J. D. (2015). Pearson's product-moment correlation: Sample analysis. ResearchGate. <https://doi.org/10.13140/RG.2.1.1856.2726> *Current Directions in Psychological Science*, 10(6), 214–219
- Cutuli, D. (2014). Cognitive reappraisal and expressive suppression strategies role in the emotion regulation: an overview on their modulatory effects and neural correlates. *Frontiers in Systems Neuroscience*, 8. <https://doi.org/10.3389/fnsys.2014.00175>
- Dixon-Gordon, K. L., Aldao, A., & De Los Reyes, A. (2015). Emotion regulation in context: Examining the spontaneous use of strategies across emotional intensity and type of emotion. *Personality and Individual Differences*, 86, 271–276. <https://doi.org/10.1016/j.paid.2015.06.011>
- English, T., & John, O. P. (2013). Understanding the social effects of emotion regulation: The mediating role of authenticity for individual differences in suppression. *Emotion*, 13, 314-329
- Feldman Barrett, L., Lane, R.D., Sechrest, L., & Schwartz, G.E. (2000). Sex differences in emotional awareness. *Personality and Social Psychology Bulletin*, 26, 1027-1035.

- Feldman JJ, Freitas AL.(2021). The generality of effects of emotional experience on emotion-regulation choice. *Emotion*;21(1):211–219. Doi:10.1037/emo0000611
- Fombouchet, Y., Pineau, S., Perchee, C., Lucenet, J., & Lannegrand, L. (2023). The development of emotion regulation in adolescence: What do we know and where to go next? *Social Development*, 32(4), 1227–1242. <https://doi.org/10.1111/sode.12684>
- Garnefski, N., Kraaij, V., & Spinhoven, P. (2001). Negative life events cognitive emotional regulation and emotional problems. *Personality and Individual Differences*, 30, 1311-1327.
- Gross JJ, John OP.(2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *J Pers Soc Psychol*;85(2):348–362. Doi:10.1037/0022-3514.85.2.348
- Gross, J. (1998). Antecedent- and response- focused emotion regulation. *Journal of Personality and Social Psychology*, 74, (1), 224-237.
- Gross, J. J. (2001). Emotion regulation in adulthood: Timing is everything.
- Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology*, 85(2), 348–362.
- Hannan SM, Orcutt HK. (2020).Emotion regulation in undergraduate students with posttraumatic stress symptoms: a multimethod study. *Psychol Trauma* ;12(6):643–650. Doi:10.1037/tra0000577
- Hay AC, Sheppes G, Gross JJ, Gruber J. (2015). Choosing how to feel: emotion regulation choice in bipolar disorder. *Emotion* ;15(2):139–145. Doi:10.1037/emo0000024
- Hofstede, G. (1980). Culture and organizations. *International Studies of Management and Organization*, 10(4), 15–41. <https://doi.org/10.1080/00208825.1980.11656300>
- John OP, Gross JJ. (2004) . Healthy and unhealthy emotion regulation: personality processes, individual differences, and life span development. *J Pers* ;72(6):1301–1333. Doi:10.1111/j.1467-1469.2004.00298.x
- Kim, J., Chun, J., Kim, J. et al. (2024). Emotion regulation from a virtue perspective. *BMC Psychol* 12, 11. <https://doi.org/10.1186/s40359-023-01490-y>

- Martin, R. E., & Ochsner, K. N. (2016). The neuroscience of emotion regulation development: implications for education. *Current Opinion in Behavioral Sciences*, 10, 142–148. <https://doi.org/10.1016/j.cobeha.2016.06.006>
- Martin, R. M. (2024). Gender differences in suppression based on type of emotion. *Psychology*, 15(06), 883–899. <https://doi.org/10.4236/psych.2024.156052>
- McRae, K., Ochsner, K. N., Mauss, I. B., Gabrieli, J. J. D., & Gross, J. J. (2008). Gender differences in emotion regulation: an fMRI study of cognitive reappraisal. *Group Processes & Intergroup Relations*, 11(2), 143–162. <https://doi.org/10.1177/1368430207088035>
- Millgram Y, Joormann J, Huppert JD, Lampert A, Tamir M. (2019). Motivations to experience happiness or sadness in depression: temporal stability and implications for coping with stress. *Clin Psychol Sci*;7(1):143–161. Doi:10.1177/2167702618797937
- Milyavsky M, Webber D, Fernandez JR, et al. (2019). To reappraise or not to reappraise? Emotion regulation choice and cognitive energetics. *Emotion*.; 19(6):964–981. Doi:10.1037/emo0000498
- Nolen-Hoeksema, S. (2012). Emotion Regulation and Psychopathology: The Role of Gender. *Annual Review of Clinical Psychology*, 8(1), 161–187. <https://doi.org/10.1146/annurev-clinpsy-032511-143109>
- Park, C. L., Williams, M. K., Hernandez, P. R., Agocha, V. B., Lee, S. Y., Carney, L. M., & Loomis, D. (2020a). Development of emotion regulation across the first two years of college. *Journal of Adolescence*, 84(1), 230–242. <https://doi.org/10.1016/j.adolescence.2020.09.009>
- Perchtold, C. M., Papousek, I., Fink, A., Weber, H., Rominger, C., & Weiss, E. M. (2019). Gender differences in generating cognitive reappraisals for threatening situations: Reappraisal capacity shields against depressive symptoms in men, but not women. *Frontiers in Psychology*, 10. <https://doi.org/10.3389/fpsyg.2019.00553>
- Preston, T., Carr, D. C., Hajcak, G., Sheffler, J., & Sachs-Ericsson, N. (2021). Cognitive reappraisal, emotional suppression, and depressive and anxiety symptoms in later life: The moderating role of gender. *Aging & Mental Health*, 26(12), 2390–2398. <https://doi.org/10.1080/13607863.2021.1998350>

Roberts, B. W., Walton, K. E., & Viechtbauer, W. (2006). Patterns of mean-level change in personality traits across the life course: A meta-analysis of longitudinal studies. *Psychological Bulletin*, 132(1), 1–25. <https://doi.org/10.1037/0033-2909.132.1.1>

Rogier, G., Garofalo, C., & Velotti, P. (2017). Is emotional suppression always bad? A matter of flexibility and gender differences. *Current Psychology*, 38(2), 411–420. <https://doi.org/10.1007/s12144-017-9623-7>

Rolston, A., & Lloyd-Richardson, E. (n.d.). Breaking the Cycle: Emotion dysregulation, reducing high emotional arousal, and self-injury. <https://www.selfinjury.bctr.cornell.edu/perch/resources/what-is-emotionalregulationsinfo-brief.pdf>

Saarni C, Mumme D, Campos JJ.(1998). Emotional development: action, communication, and understanding. In: Eisenberg N, editor. Handbook of child psychology: Vol. 3 Social, emotional and personality development. 5 th ed. *New York: Wiley*; 1998. Pp. 237–309.

Sauer C, Sheppes G, Lackner HK, Arens EA, Tarrasch R, Barnow S. (2016). Emotion regulation choice in female patients with borderline personality disorder: findings from self-reports and experimental measures. *Psychiatry Res.* ;242:375–384. Doi:10.1016/j.psychres.2016.04.113

ScienceDirect. (n.d.). SPSS statistics. ScienceDirect. Retrieved January 26, 2025, from <https://www.sciencedirect.com/topics/social-sciences/spss-statistics>

Sheppes G, Scheibe S, Suri G, Radu P, Blechert J, Gross JJ. (2014). Emotion regulation choice: a conceptual framework and supporting evidence. *J Exp Psychol Gen.* 2014;143(1):163–181. Doi:10.1037/a0030831

Spaapen, D. L., Waters, F., Brummer, L., Stopa, L., & Bucks, R. S. (2014). The Emotion Regulation Questionnaire: Validation of the ERQ-9 in two community samples. *Psychological Assessment*, 26, 1-7.

Suri G, Sheppes G, Young G, Abraham D, McRae K, Gross JJ. (2018). Emotion regulation choice: the role of environmental affordances. *Cogn Emoti* ;32(5):963–971. Doi:10.1080/02699931.2017.1371003

Tamir M, Ford BQ, Gilliam M. (2013). Evidence for utilitarian motives in emotion regulation. *Cogn Emot.* ;27(3):483–491. Doi:10.1080/02699931.2012.715079

Verzeletti, C., Zammuner, V. L., Galli, C., & Agnoli, S. (2016). Emotion regulation strategies and psychosocial well-being in adolescence. *Cogent Psychology*, 3(1), 1199294. <https://doi.org/10.1080/23311908.2016.1199294>

Vishkin A, Hasson Y, Millgram Y, Tamir M.(2020) One size does not fit all: tailoring cognitive reappraisal to different emotions. *Pers Soc Psychol Bull.* ;46(3):469–484. Doi:10.1177/0146167219861432

Wadhwa, R. R., & Marappa-Ganeshan, R. (n.d.). T test. In StatPearls. Retrieved January 26, 2025, from <https://www.ncbi.nlm.nih.gov/books/NBK553048/>

Wiltink, J., Glaesmer, H., Canterino, M., Wolfling, K., Knebel, A., Kessler, H., . . . Buetel, M. E. (2011). Regulation of emotions in the community: Suppression and reappraisal strategies and its psychometric properties. *Psycho-Social Medicine*. 8, 1-12

Wu, W., Wu, H., Wu, X., Gu, J., & Qi, X. (2024). A meta-analysis of life satisfaction's association with cognitive reappraisal and expressive suppression: the influences of age, gender, and cultural values. *Journal of Happiness Studies*, 25(4). <https://doi.org/10.1007/s10902-024-00753-8>

Yan XY, Gao W, Yang JM, Yuan JJ. (2022). Emotion regulation choice in internet addiction: less reappraisal, lower frontal alpha asymmetry. *Clin EEG Neurosci.* ;53(4):278–286. Doi:10.1177/15500594211056433

Yellapu, V. (2018). Descriptive statistics. *International Journal of Academic Medicine*, 4(1), 60. https://doi.org/10.4103/IJAM.IJAM_7_18

Young G, Suri G. (2020) . Emotion regulation choice: a broad examination of external factors. *Cogn Emot.* ;34(2):242–261. Doi:10.1080/02699931.2019.1611544

Zhang N, Zhang K, Wang J, Sun X (2022) Distract or reappraise? the mechanism of cognitive emotion regulation choice and its influential factors. *Psychology Research and Behaviour Management*, Vol.15 DOI <https://doi.org/10.2147/PRBM.S389835>

Zhylin, M., Mendelo, V., Bondarevych, S., Kokorina, Y., & Tatianchykov, A. (2024). Genetic basis of emotional regulation: integrative analysis of behavioral and neurobiological data. *OBM Neurobiology*, 08(04), 1–21. <https://doi.org/10.21926/obm.neurobiol.2404256>

Zimmermann, P., & Iwanski, A. (2014). Emotion regulation from early adolescence to emerging adulthood and middle adulthood. *International Journal of Behavioral Development*, 38(2), 182–194. <https://doi.org/10.1177/0165025413515405>

4

Solid Waste Management in a VUCA World*Infant Leonard, Praveen Minj, Raizel Rebello*

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Abstract

The management of solid waste in a VUCA (Volatile, Uncertain, Complex, Ambiguous) world demands innovative approaches that blend sustainability with advanced technologies. This paper explores the transformative role of Artificial Intelligence (AI) in developing sustainable solid waste management systems. Leveraging AI-driven predictive analytics, smart waste segregation, and efficient resource recovery, the study outlines pathways to reduce environmental footprints while fostering circular economy principles. By addressing the challenges posed by urbanisation, climate variability, and resource scarcity, AI-enabled systems can enhance adaptability and resilience in waste management infrastructure. The research further investigates ethical considerations, scalability, and the integration of community-centric models, ensuring inclusivity in implementation. Through interdisciplinary collaboration, this work contributes to the Sustainable Development Goals (SDGs), emphasising the role of AI in achieving a cleaner and more sustainable future amidst the complexities of a VUCA landscape.

Keywords - Solid Waste Management, Artificial Intelligence, Sustainability, Circular Economy, VUCA, Resilience, SDGs

Managing solid waste is a major challenge, especially in fast-growing countries like India. With cities expanding and more waste being produced, finding efficient and sustainable ways to handle waste has become crucial. Right now, waste management mostly depends on human workers who collect, sort, and recycle waste. While these workers are essential, the increasing complexity of waste disposal calls for new ways to improve the system. Artificial Intelligence (AI) has started making an impact in various industries, including waste management. AI can help predict waste patterns, improve sorting, and make recycling more efficient. However, introducing AI into waste management in India needs careful thought. The Safai Bank of India, which promotes responsible waste management, is a great example of a system that relies mostly on human effort.

Our study explores how AI can be used in such setups to enhance processes without taking jobs away from workers. A major concern with AI in waste management is that it could replace human workers, making unemployment worse in a country already struggling with job opportunities. Instead of replacing workers, AI should be used in areas where human efforts fall short or where the work is risky. For example, hazardous waste handling is dangerous, and AI-driven robots could take over these tasks to keep workers safe. At the same time, AI can improve working conditions for waste workers. By automating physically demanding or unsafe tasks, AI could make the waste management sector more efficient and organized. AI-powered sorting machines, for example, could help separate recyclable materials more accurately, reducing the burden on human workers. This would improve recycling rates while allowing workers to focus on tasks that require human judgment and oversight.

However, implementing AI in waste management must balance technological progress with social and economic impact. This research explores how AI can support, rather than replace, human workers in waste management. We interviewed Mr. Rishi Agarwal, a representative of the Safai Bank of India, to understand how AI could be integrated while ensuring job security. Our study also looks into ethical issues, practical challenges, and ways to balance human skills with technology. By exploring these ideas, we hope to find ways that AI can improve waste management while also being fair to workers. This research contributes to discussions on sustainability, showing how AI and human workers can collaborate to help India achieve its Sustainable Development Goals (SDGs) in an effective and fair manner. AI should not be seen as a threat to employment but as an opportunity to enhance efficiency, improve working conditions, and promote a cleaner and more sustainable future.

Review of Literature

The population of India has been growing exponentially. It was not too long ago that India overtook China to become the most populous country in the world. India has shown a growth spurt of 17.71% between 2001 to 2011. According to the census reports, approximately 1210 million people resided in India. With 68.85% of the population still residing in the rural areas and the rest constituting the Urban population (Census_of_India_2011_GOI, 2011). To cater to all these needs of this ever-growing population, India has stepped into a phase of fast-track development. The onset of development has brought about significant changes in the accessibility of resources, which, on the other hand, has triggered an increase in the per capita consumption of resources amongst the people. The immediate effect of the same has been observed in the waste generated, especially in the urban cities of India. The change in the economic policies providing leeway to abrupt industrialisation to boost the economy has been equally detrimental because of its overall impact on the environment. The urban expansions and migrations in search of gainful employment have heavily polluted the urban areas, and the issue of solid waste management has been looming over the government body to tackle (Saifi, N., & Jha, B. 2024). Although positivists would see this as an excellent opportunity for India, looking at its potential labour force, which proves to be a very important factor as many developed countries are facing a declining labour force, what we need to consider is its environmental impact overall.

The sustainable development report largely discusses the issue of e-waste in the context of solid waste management. There has been a significant rise in the per capita e-waste generation from 6.3 kg in 2015 to 7.8 kg in 2022, which accounts for nearly 62 million metric tonnes. The developed or high-income countries are managing a good margin of 40% e-waste retrieval, despite this, it is disconcerting to know that only 1.7 kgs per capita of e-waste was collected and managed in an environmentally friendly manner. It is projected in the report that by 2030 the e-waste is going to spike up to 10 kgs per capita which would amount to 82 million metric tonnes, if the collection is scaled up to 60% globally then only we would be able to achieve a sustainable way of managing the e-waste and curb its related issues (United Nations Department of Economic and Social Affairs, 2024). It is to be noted that most of the waste management in all the lower-income countries is majorly handled by the informal sector; this amounts to malpractices, problematic collections and unethical disposal, causing environmental and health hazards. In India, as well, we see a similar trend where majorly the

informal sector is employed in waste management. While we see a few exceptions like Pune, India, where the informal sector organized by union like *Kagad Kach Patra Kashtakari Panchayat* (KKPKP) formed an MoU with the Pune municipal corporation and have formed a SWaCH Team that aligns with the National solid waste management policy where the municipal corporation is assigned to operationalise and coordinate safe collection, segregation, processing, transport and disposal of waste. This particular model has been instrumental in the decentralisation of the collection and segregation of solid waste in a sustainable and healthy manner, plus it is also incentive-based for the workers employed in SWaCH (Saifi, N., & Jha, B. 2024). However, these models are very few, and many lower-income countries still grapple with the question of sustainable solid waste management, which results in severe health hazards due to the toxic emissions.

The traditional waste management system is seen to be full of loopholes and needs measures dealing with the issues pertaining to collecting, sorting, transport and disposal/landfill in a more efficient and sustainable way. The answer to all these inquiries has led a lot of researchers towards the use of AI in solid waste management. Different types of waste need different types of treatment and management strategies. By having a sound understanding of AI and by employing AI-driven models the problem of waste management can be dealt with in a much more efficient manner, like it can optimize waste to energy conversion processes by making them more sustainable by collecting data through imaging, etc. and showing trends and accordingly forecasting strategies for the same. A comparative study of AI-based prediction models like Cubists, Support Vector Machine (SVM), Random Forest (RF), and Bayesian Artificial Neural Network (ANN) showed that Cubists has a comparatively better output and performance compared to others (Vanya Arun, 2024).

The AI-based learning techniques outperform the traditional statistical models of forecasting, reducing the fuel consumption and carbon footprint by the employment of automated waste collection vehicles and smart bins, with IoT sensors, there real-time data is available for better management of waste. While Trash Bot technology has revolutionised the waste segregation into recyclable and non-recyclable, AI-powered waste tracking can be very handy in terms of optimising the collection; these are very helpful in the reduction of waste sent to landfill, thus in a way contributing to waste-to-energy conversion. What it also does is that it keeps a check on the illegal dumping that has been rampant in urban cities, it helps in regulating pollution and exposure to hazardous waste (Vivek Sarraf et al., 2024) .

In the works of Fang et al., they have claimed that the “*Artificial intelligence in waste logistics can reduce transportation distance by up to 36.8%, cost savings by up to 13.35%, and time savings by up to 28.22%. Artificial intelligence allows for identifying and sorting waste with an accuracy ranging from 72.8 to 99.95%*” (Fang et al.), all these statistics posit a very promising future, wherein we can say that AI is the best foot forward towards tackling the problem of waste, however one cannot rule out the issues that come with application of AI. The ethical and privacy concerns that arise with the usage of AI, which we all are aware of cannot be swept under the carpet, the need for robust policies regulating the ethical use of AI in the waste management, lastly the need for skilled labour force to work on AI-powered models and the large operational cost it incurs cannot be ignored.

Thus although the issue of solid waste management has been something that the entire world has been grappling with, and the SDG’s are marred with series of incompetencies both human and technological, still what lies at the heart of all the discussion made thus far is the efficient usage of AI for the betterment of the society. Although there are contrasting views regarding both its benefits and concerns, the benefits still comparatively outweigh the cons, which can be optimised through different policy interventions.

A Case Study of Safai Bank of India

The waste management scenarios have worsened across the globe due to rapid urbanisation, changing consumption patterns, and the proliferation of non-biodegradable materials. These challenges are more evident in India due to its vast population and diverse social as well as economic landscape.

Purpose

This case study aims to understand and explore the solid waste management strategies in the VUCA environment. Focusing and examining the approach employed by Safai Bank of India, we look forward to identifying best practices, challenges, and areas of improvement, particularly with respect to integrating manual labour and technological solutions.

About Safai Bank of India

The Safai Bank of India was established in 2018, as an effort towards addressing India’s most serious environmental issue of plastic waste, specifically of the Multi-layered Plastic (MLP).

MLP is extensively used in the packaging of Fast-Moving Consumer Goods (FMCGs) such as chips, chocolates and detergent packets. These FMCGs that come in MLP are non-recyclable in nature. This contributes significantly to environmental pollution.

Safai Bank of India (SBI) is based on a mission “to divert millions of items of multi-laminated packaging waste from reaching dumping grounds of Indian cities. They aim to provide an effortless platform for millions of families to take responsibility for their waste.”

The SBI operates like a bank where individuals and organisations can deposit their waste. This approach promotes participation and responsibility in waste management. Individuals commit to collecting and depositing their plastic waste at specific branches. These branches are set up in educational institutions, offices, and residential societies. The registered individuals are referred to as account holders. After a specific amount is collected, it is then disposed of through methods prescribed in the rules stated in the Waste Management Act of 2016.

This decentralised approach ensures that waste is managed at the source, reducing the burden on municipal waste management systems.

Findings from the Interview with Safai Bank of India

In the interview with Mr. Rishi Agarwal, a representative of the Safai Bank of India, several key aspects were highlighted:

- **Manufacturer's Responsibility for Multi-Layered Plastic:**

The SBI promotes the concept of Extended Producer Responsibility (EPR), urging the manufacturers of products that produce MLP to be responsible for their disposal.

- **Waste Management Development Plan:**

The organisation has developed a detailed plan to ensure the collection, segregation and safe disposal of MLP. The plan lists down planned standard operating procedures to carry out the step-by-step process of collection, segregation, and disposal. This plan meets a number of SDGs, such as SDG 11 Sustainable Cities and Communities, SDG 12 Responsible Consumption and Production and SDG 13 Climate Action.

- **Waste Segregation and Manual Labour:**

At these centres, a team of approximately 50 individuals manually segregates around 20-22 tons of dry waste daily. Standard Operating Procedures (SOPs) are used to ensure safety and consistency in the segregation process. Use of manual labour creates opportunities for employment and is best when handling complex types of waste.

Best Practices

- **Collaboration with the Brihanmumbai Municipal Corporation (BMC)**

Recognising the need of the city, the SBI has 35 Dry Waste Management Centres and 266 branches across Mumbai. These centres work in collaboration with the Brihanmumbai Municipal Corporation (BMC). The collaboration ensures that the SBI works within the framework of the Solid Waste Management Rules, 2016. It also provides a solution to the MLP waste by using it for road construction.

- **Decentralization Techniques**

The organisation's decentralised model empowers local communities to take charge of their waste management. By establishing multiple branches, they ensure that waste collection and segregation occur close to the source, thereby increasing efficiency and community involvement.

- **Community Engagement:**

SBI has taken the efforts to collaborate with over 200 schools and colleges across India to promote student engagement and increase awareness through programs, workshops, competitions, collection drives, and awareness campaigns about sustainability and plastic pollution. Along with this, they also partnered with corporate entities and business organisations, which incorporated sustainable waste disposal into corporate social responsibility (CSR) initiatives.

- **Employment Generation:**

According to the Development plan, most of the segregation of dry waste is handled manually. On an average, around 50 workers can segregate 20-22 tons of dry waste per day. Due to the complexities in identifying the dry waste, manual labour has been approved to be more effective. This has led to employment generation for many economically disadvantaged groups.

- **Technological Use:**

SBI primarily focuses on community engagement and manual process for waste management. They make use of transportation machinery to transport the collected waste. Major technological tools are used in the later part for disposing the waste.

Analysis

The Safai Bank of India has overall led to a sustainable impact by promoting responsible disposal practices. Its constant engagement with the community has led to awareness and a reduction in plastic pollution to some extent. The initiative is effective due to its plan of development and its decentralised approach towards waste management. It encourages sustainable practices within the community through its constant engagement with educational institutions, corporate sectors of work and residential societies.

In terms of using manual labour in the segregation of waste has led to generating employment that supports individuals as well as the local economy. Due to the diverse and unpredictable nature of waste materials, especially in contexts where the waste is not previously segregated, manual labourers are more effective than machines. On the other hand, this can also lead to the workers being exposed to unsanitary conditions for a longer period of time. This can cause health issues if protective measures are not taken. With the vast volumes of waste, manual processes can be tedious and time-consuming. Despite playing an important role in the solid waste management system, the workers receive minimal wages, these wages do not reflect any structured healthcare support.

Though the SBI primarily depends on manual labour, there is potential scope for the use of AI tools and technology to enhance efficiency. Tools such as AI-designed tools for automatic sorting can significantly improve the speed and accuracy of the segregation of waste. This will reduce the risk of health hazards for the workers. Data analytics tools can help keep track on the generation of waste and keep information records, which would also allow authorities and organisations to keep track of the work and develop more strategies for effective waste management.

Implementing AI tools and technology in India may not be feasible and will require substantial capital investment. These tools will also require specialised skills for implementation and extra costs for maintenance. These tools can cause disruption, with the workers losing their jobs and scope to earn a livelihood. To address such challenges about the integration of AI tools and

Technology, there can be small-scale projects to check the effectiveness of such tools, their efficiency and cost effectiveness. Various strategies, such as collaboration with technology firms and academic institutions, can provide access to expertise and funding. It can make waste management more affordable and feasible.

Data Analysis

We have referred to the official website of the Government of India – Ministry of Statistics and Programme Implementation to gather data on unemployment in our country, India. The original Excel Sheet, as downloaded, is converted to pdf and has been attached in the appendix section. For analysis' sake, I have divided the data into two categories of employment and unemployment individually among MALE, FEMALE and PERSON (LGBTQIA+). Before the analysis, certain terms require clarification.

Definitions of Employment Categories:

1. Self-Employed: Individuals who work for themselves rather than being employed by an organisation. This includes:
 - Own account worker, employer: Business owners or freelancers.
 - Helper in household enterprise: Individuals assisting in a family-run business.
2. Regular Wage/Salary Earners: Those employed with a fixed wage or salary, usually in formal jobs.
3. Casual Labour: Workers engaged in temporary or daily wage jobs, often without job security.
4. Unemployed: Individuals who are actively looking for work but do not have any employment.
5. Not in Labour Force: People who are neither working nor actively looking for jobs (e.g., students, homemakers, retired persons).

Analysis of Employment and Unemployment Across Four Quarters (2023-2024)

This report looks at employment and unemployment trends for people aged 15 and above over four different quarters: October-December 2023, January-March 2024, April-June 2024, and July-September 2024. The data shows how people were engaged in self-employment, regular jobs, casual labour, unemployment, or not in the labour force.

Table 1: October - December 2023**Key Takeaways:**

- About 61.3% of people were employed, with 32.7% in salaried jobs and 28.1% self-employed.
- The unemployment rate was 4.2%, with the rest either employed or not looking for work.
- 25.9% were not in the labor force, meaning they weren't working or looking for jobs.

What This Means:

- A big chunk of people were self-employed (28.1%), meaning many relied on their own businesses or freelance work.
- Regular jobs (32.7%) were the largest category, showing that salaried work was the most stable form of employment.
- Unemployment wasn't too high (4.2%), but a lot of people (25.9%) weren't even in the job market, possibly because of education, family responsibilities, or lack of job opportunities.

Table 2: January - March 2024**Key Takeaways:**

- Employment was 61.1%, almost the same as the last quarter.
- Unemployment increased slightly to 4.5% from 4.2%.
- Fewer people were out of the labour force (25.8% compared to 25.9% in the previous quarter).

What This Means:

- More people may have started looking for work after the holiday season, which is why the unemployment rate went up a little.
- Salaried jobs (32.9%) increased slightly, meaning more people got steady jobs.
- The percentage of casual workers (8.6%) stayed the same, meaning temporary work didn't change much.

Table 3: April - June 2024**Key Takeaways:**

- Employment increased to 61.7%, which was higher than in the previous two quarters.
- Unemployment went down to 4.1%, showing more people found jobs.
- Fewer people were not in the labour force (25.4%).

What This Means:

- More people got jobs, possibly because of seasonal hiring or economic growth.
- Salaried jobs increased to 33.7%, which is a good sign for the economy.
- Since fewer people were unemployed (4.1%) and more were employed, it suggests better job availability or lower job losses.

Table 4: July - September 2024**Key Takeaways:**

- Employment dropped slightly to 58.2% from 61.7% in the last quarter.
- Unemployment stayed at 4.1%, so job losses didn't lead to more unemployed people.
- More people were not in the labour force (25.9%, up from 25.4% in the last quarter).

What This Means:

- Some people may have lost jobs or left the workforce (possibly due to seasonal factors).
- Salaried jobs were still growing (33.0%), so stable job opportunities remained.
- Since unemployment didn't increase, it suggests some people who left their jobs may have stopped looking for work instead of becoming unemployed.

Overall Summary

- Employment stayed between 58-61% throughout the year.
- Salaried jobs and self-employment were the biggest sources of work.
- Unemployment was stable at around 4.1% - 4.5%, meaning job conditions didn't change drastically.
- About 25% of people were not in the labour force, likely due to school, family responsibilities, or discouragement from job hunting.
- More people found stable jobs in the middle of the year, but employment dropped slightly towards the end.

Final Thoughts

The job market remained pretty stable, with salaried jobs growing slightly and unemployment staying low. However, a large number of people were still out of the workforce, which could mean many are either not interested in working or struggling to find opportunities. AI and Jobs: A Balanced Approach in a Changing World

Looking at the employment data from 2023-2024, we can see that 58-61% of people had jobs, while 4.1-4.5% were unemployed. However, a large chunk (25-26%) wasn't even in the labour force, meaning they weren't working or looking for jobs. If AI completely took over traditional jobs, this percentage could rise even more, leading to fewer job opportunities and greater economic struggles.

In today's fast-changing world, AI is often seen as a solution to many challenges, but replacing human workers with AI isn't the answer. While AI can make things more efficient—like sorting waste, handling dangerous materials, or predicting trends, fully automating jobs could leave millions unemployed. The data already shows that many people struggle to find work, and if AI takes over too much, the situation could get worse.

Instead of replacing people, AI should be used to support human workers, helping in areas where humans have limitations. It can take care of physically exhausting, repetitive, or hazardous tasks, while humans focus on things that require decision-making, creativity, and emotional intelligence. By using AI as a tool rather than a full replacement, we can improve efficiency without putting too many people out of work. The goal should be to find a balance where technology makes jobs easier and safer, but people still have opportunities to work and earn a living.

Table 1:

Activity status in CWS during october - december 2023, 15 years and above							
<i>Male</i>							
	<i>Self employed</i>	<i>regular wage/ Salary</i>	<i>Casual labour</i>	<i>Unemployed</i>	<i>Not in labour force</i>	<i>Empl oyed</i>	<i>Une mplo yed</i>
own account worker, employer	24.0	0.2	0.2	0.1	0.2	24.2	0.5
helper in household enterprise	3.2	*	*	*	0.1	3.2	0.1
self employed	27.8	0.3	0.2	0.1	0.3	28.1	0.6
regular wage/ salary	0.3	31.7	0.1	0.3	0.1	32.0	0.5
casual labour	0.2	0.2	7.7	0.4	0.2	0.4	8.3
unemploy ed	0.2	0.4	0.3	3.3	0.1	0.6	3.7
not in labour force	0.2	0.2	0.1	0.2	25.2	0.4	25.5
all (Total)	28.6	32.7	8.6	4.2	25.9	61.3	38.7

<i>Female</i>							
own account worker, employer	5.5	0.1	*	*	0.4	5.6	0.4
helper in househol d enterpris e	2.7	*	*	*	0.2	2.7	0.2
self employe d	8.3	0.1	*	*	0.7	8.4	0.7
regular wage/ salary	*	11.1	*	0.1	0.3	11.1	0.4
casual labour	*	*	1.3	0.1	0.2	0.0	1.6
unemplo yed	*	0.1	0.1	1.6	0.2	0.1	1.9
not in labour force	0.7	0.5	0.2	0.2	74.2	1.2	74.6
all (Total)	9.1	11.8	1.6	2.0	75.6	20.9	79.2

<i>Persons</i>							
own account worker, employer	14.7	0.1	0.1	0.1	0.3	14.8	0.5
helper in househol d enterpris e	3.0	*	*	*	0.2	3.0	0.2
self employe d	18.1	0.2	0.1	0.1	0.5	18.3	0.7
regular wage/ salary	0.2	21.4	0.1	0.2	0.2	21.6	0.5
casual labour	0.1	0.1	4.5	0.2	0.2	0.2	4.9
unemplo yed	0.1	0.3	0.2	2.4	0.2	0.4	2.8
not in labour force	0.4	0.3	0.2	0.2	49.7	0.7	50.1
all (Total)	18.8	22.3	5.1	3.1	50.7	41.1	58.9

Table 2:

Activity status in CWS during January - March 2024, 15 years and above							
<i>Male</i>							
	<i>Self empl oyed</i>	<i>regular wage/Sal ary</i>	<i>Casu al labo ur</i>	<i>Une mpl oyed</i>	<i>Not in labour force</i>	<i>Emp loye d</i>	<i>Une mplo yed</i>
own account worker, employer	23.7	0.3	0.1	0.1	0.2	24.0	0.4
helper in household enterprise	3.0	*	*	*	0.1	3.0	0.1
self employed	27.4	0.3	0.2	0.2	0.3	27.7	0.7
regular wage/ salary	0.3	32.1	0.2	0.4	0.1	32.4	0.7
casual labour	0.2	0.1	7.7	0.5	0.1	0.3	8.3
unemployed	0.1	0.2	0.4	3.4	0.1	0.3	3.9
not in labour force	0.2	0.1	0.2	0.1	25.2	0.3	25.5
all (Total)	28.2	32.9	8.6	4.5	25.8	61.1	38.9

<i>Female</i>							
own account worker, employer	5.7	0.1	*	*	0.4	5.8	0.4
helper in household enterprise	2.7	*	*	*	0.3	2.7	0.3
self employed	8.8	0.1	*	*	0.7	8.9	0.7
regular wage/ salary	0.1	11.5	*	0.1	0.3	11.6	0.4
casual labour	0.1	*	1.2	0.1	0.2	0.1	1.5
unemployed	*	0.1	0.1	1.8	0.2	0.1	2.1
not in labour force	0.6	0.3	0.1	0.2	73.5	0.9	73.8
all (Total)	9.5	12.0	1.4	2.1	74.9	21.5	78.4

<i>Persons</i>							
own account worker, employer	14.7	0.2	0.1	0.1	0.3	14.9	0.5
helper in household enterprise	2.9	*	*	*	0.2	2.9	0.2
self employed	18.1	0.2	0.1	0.1	0.5	18.3	0.7
regular wage/ salary	0.2	21.8	0.1	0.2	0.2	22.0	0.5
casual labour	0.1	0.1	4.4	0.3	0.2	0.2	4.9
unemployed	0.1	0.1	0.2	2.6	0.1	0.2	2.9
not in labour force	0.4	0.2	0.2	0.2	49.4	0.6	49.8
all (Total)	18.8	22.4	5.0	3.3	50.4	41.2	58.7

Table 3:

Activity status in CWS during April - June 2024, 15 years and above							
<i>Male</i>							
	<i>Self empl oyed</i>	<i>regular wage/Sal ary</i>	<i>Casu al labo ur</i>	<i>Une mpl oye d</i>	<i>Not in labou r force</i>	<i>Empl oyed</i>	<i>Une mplo yed</i>
own account worker, employer	23.8	0.2	0.1	0.1	0.1	24.0	0.3
helper in household enterprise	3.1	*	*	*	0.1	3.1	0.1
self employed	27.5	0.2	0.1	0.1	0.2	27.7	0.4
regular wage/ salary	0.2	32.2	0.1	0.3	0.1	32.4	0.5
casual labour	0.1	0.1	8.1	0.3	0.1	0.2	8.5
unemployed	0.2	0.3	0.4	3.6	0.1	0.5	4.1
not in labour force	0.1	0.1	0.1	0.1	25.1	0.2	25.3
all (Total)	28.2	32.9	8.9	4.4	25.7	61.1	39.0

<i>Female</i>							
own account worker, employer	5.9	0.1	0.1	*	0.5	6.0	0.6
helper in household enterprise	2.6	*	*	*	0.4	2.6	0.4
self employed	8.7	0.1	0.1	*	0.9	8.8	1.0
regular wage/ salary	0.1	11.9	*	0.1	0.3	12.0	0.4
casual labour	*	*	1.2	0.1	0.2	0.0	1.5
unemployed	*	0.1	0.1	1.8	0.2	0.1	2.1
not in labour force	0.5	0.3	0.1	0.2	73.0	0.8	73.3
all (Total)	9.4	12.3	1.4	2.2	74.7	21.7	78.3

<i>Persons</i>							
own account worker, employer	14.8	0.1	0.1	*	0.3	14.9	0.4
helper in household enterprise	2.8	*	*	*	0.2	2.8	0.2
self employed	18.1	0.2	0.1	0.1	0.6	18.3	0.8
regular wage/ salary	0.1	22.0	0.1	0.2	0.2	22.1	0.5
casual labour	0.1	0.1	4.6	0.2	0.2	0.2	5.0
unemployed	0.1	0.2	0.2	2.7	0.2	0.3	3.1
not in labour force	0.3	0.2	0.1	0.1	49.0	0.5	49.2
all (Total)	18.8	22.6	5.2	3.3	50.2	41.4	58.7

Table 4:

Activity status in CWS during July - September 2024, 15 years and above							
<i>Male</i>							
	<i>Self employed</i>	<i>regular wage/Salary</i>	<i>Casual labour</i>	<i>Unemployed</i>	<i>Not in labour force</i>	<i>Employed</i>	<i>Unemployed</i>
own account worker, employer	23.7	0.2	0.1	0.1	0.1	23.9	0.3
helper in household enterprise	2.8	*	*	*	0.1	2.8	0.1
self employed	27.3	0.2	0.1	0.1	0.2	27.5	0.4
regular wage/salary	0.3	33.0	0.1	0.3	0.2	33.3	0.6
casual labour	0.2	0.1	8.1	0.5	0.2	0.3	8.8
unemployed	0.1	0.3	0.4	3.1	0.1	0.4	3.6
not in labour force	0.2	0.1	0.1	0.1	24.7	0.3	24.9
all (Total)	28.0	33.7	8.8	4.1	25.4	61.7	38.3

<i>Female</i>							
own account worker, employer	5.9	0.1	*	*	0.4	6.0	0.4
helper in household enterprise	2.3	*	*	*	0.2	2.3	0.2
self employed	8.3	0.1	*	*	0.6	8.4	0.6
regular wage/ salary	0.1	12.0	*	0.1	0.3	12.1	0.4
casual labour	*	*	1.1	0.1	0.2	0.0	1.4
unemployed	*	0.1	0.1	1.7	0.2	0.1	2.0
not in labour force	0.7	0.3	0.2	0.2	73.5	1.0	73.9
all (Total)	9.2	12.6	1.3	2.2	74.8	21.8	78.3

<i>Persons</i>							
own account worker, employer	14.8	0.1	*	*	0.2	14.9	0.2
helper in household enterprise	2.6	*	*	*	0.1	2.6	0.1
self employed	17.8	0.2	0.1	0.1	0.4	18.0	0.6
regular wage/ salary	0.2	22.5	*	0.2	0.3	22.7	0.5
casual labour	0.1	*	4.6	0.3	0.2	0.1	5.1
unemployed	0.1	0.2	0.2	2.4	0.2	0.3	2.8
not in labour force	0.4	0.2	0.2	0.2	49.2	0.6	49.6
all (Total)	18.6	23.1	5.0	3.1	50.1	41.7	58.2

Conclusion

The entire paper posits that an a priori condition in the VUCA (Volatile, Uncertain, Complex, and Ambiguous) world is that solid waste management needs urgent attention. Sustainable strategies that are both a mix of innovative approaches with a balanced integration of human as well as technological interventions. This research indicates the unparalleled potential that AI holds in waste management, through its predictive analytics to enhance sustainability, simultaneously reducing the overall environmental impact. However, it also addresses the flip side of AI, which still remains to be its ethical concerns, and the long-debated technology over human labour or vice-versa still remains at the heart of the discussion. The study highlights the importance of the need for balance between automation and human labour, it upholds economic inclusivity and job security, especially for the socio-economically vulnerable sections of society dependent on livelihoods based on waste management.

Through this paper, when we analyse the case study of Safai Bank of India, we come to the conclusion that technology need not be the only solution, but rather a supplement to the solutions. What we submit is that having a Community Driven model- inviting Public Private Participation (PPP), Decentralisation of collection and segregation, can take the load of the piles and mountains of landfill we have been generating. Along with this, we also need ground-level engagement programs that challenge the rudimentary practices of waste collection, segregation and disposal at the very primary levels of household waste and promote environmentally friendly practices. It is observed that there is a sense of complacency that settles in amongst the people who act out very enthusiastically at the inception, regular engagements and follow-up are needed to back the effort of inculcating environmentally friendly practices.

There are pros and cons to the use of AI and Technology. Instead of completely replacing manual labour with AI, we must find a balance between the use of technology and manual labour. Most of the people employed in this sector are lower-income, socio-economically and socio-culturally marginalised groups. There should be enough incentives for them to continue with their livelihood and a need for their capacity building to equip them with the technological advancements in the fields of solid waste management. Lastly, in areas like solid waste management, if we humans do not take the onus upon us to change the existing practices of exploiting the resources of nature and polluting without having remorse for our act, then, even with the best of technological equipment and AI tools we would not be able to find a solution to reduce and eliminate excessive waste that is piling up on the earth.

References

- About - Safai Bank of India. (2023, July 17). Safai Bank of India. <https://safaibank.org/about-safai-bank/>
- Bank, S. (2022, June 1). How does the bank work? - Safai Bank of India. Safai Bank of India. <https://safaibank.org/educating-people/>
- Thacker, H. (2020, July 28). CSR: Safai Bank of India - An answer to tackle MLP waste - The CSR Journal. The CSR Journal. <https://thecsrjournal.in/csr-safai-bank-of-india-an-answer-to-tackle-mlp-waste/>
- Mathur, B. (2020, April 15). A bank with a green mission: the Safai Bank of India aims to prevent plastic wrappers from ending up in landfills. NDTV-Dettol Banega Swasth Swachh India. <https://swachhindia.ndtv.com/bank-with-a-green-mission-safai-bank-of-india-aims-to-keep-plastic-wrappers-from-landfills-41137/>
- Patel, R. (2024, February 21). Overcoming 8 waste management challenges in 2025. Upper Route Planner. <https://www.upperinc.com/blog/waste-management-challenges/>
- Arun, V., Rao, K., Anusuya, V.S., Nagpal, A., Chandra, P.K., & Albawi, A. (2024). AI based prediction algorithms for enhancing the waste management system: A comparative analysis. E3S Web of Conferences.
- Azevedo, B. D., Scavarda, L. F., Caiado, R. G. G., & Fuss, M. (2021). Improving urban household solid waste management in developing countries based on the German experience. *Waste Management*, 120, 772–783. <https://doi.org/10.1016/j.wasman.2020.11.001>
- Batista, M., Caiado, R. G. G., Quelhas, O. L. G., Lima, G. B. A., Filho, W. L., & Yparraguirre, I. T. R. (2021). A framework for sustainable and integrated municipal solid waste management: Barriers and critical factors to developing countries. *Journal of Cleaner Production*, 312, 127516. <https://doi.org/10.1016/j.jclepro.2021.127516>
- Census_of_India_2011_GOI. (2011). *Census of India 2011 provisional population totals*. https://censusindia.gov.in/2011-prov-results/paper2/data_files/india2/1_data_highlight.pdf
- Fang, B., Yu, J., Chen, Z., et al. (2023). Artificial intelligence for waste management in smart cities: A review. *Environmental Chemistry Letters*, 21, 1959–1989. <https://doi.org/10.1007/s10311-023-01604-3>
- Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). *What a waste 2.0: A global snapshot of solid waste management to 2050*. <http://datatopics.worldbank.org/what-a-waste/>
- Melinda, V., Williams, T., Anderson, J., Davies, G., & Davis, C. (2024). Enhancing waste-to-energy conversion efficiency and sustainability through advanced artificial intelligence

- integration. *International Transactions on Education Technology*, 2(2), 183–192. <https://doi.org/10.33050/itee.v2i2.597>
- Saifi, N., & Jha, B. (2024). An overview of solid waste management practices in Pune, Maharashtra, India. *Nature Environment and Pollution Technology*, 23(2), 923–934. <https://doi.org/10.46488/NEPT.2024.v23i02.027>
- Sarraf, V., Purohit, R. R., Jain, A., Jain, R., Yashwanth, M., Mathews, A., & VaraLakshmi, S. (2024). A study on AI-powered waste management. *International Journal of Research Publication and Reviews*, 5(3), 3618–3625. <https://doi.org/10.55248/gengpi.5.0324.0793>
- United Nations Department of Economic and Social Affairs. (2024). *The Sustainable Development Goals Report 2024*. United Nations. <https://unstats.un.org/sdgs/report/2024/The-Sustainable-Development-Goals-Report-2024.pdf>
- Xu, A., Chang, H., Xu, Y., Li, R., Li, X., & Zhao, Y. (2021). Applying artificial neural networks (ANNs) to solve solid waste-related issues: A critical review. *Waste Management*, 124, 385–402. <https://doi.org/10.1016/j.wasman.2021.02.029>

5

Beyond the Code: Gender, Ethics and AI in Cinematic Narratives*Kanishk Sharma**Khyati Kapoor*

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Abstract

It's wild, really—machines that once just answered questions or played music are now quietly influencing how we think about relationships, about what it means to be a man or a woman, about power, care, and control. It's not just code and circuits anymore. It's us. Our feelings, our identities, our very human messiness—all now part of this digital mix. And whether we realize it or not, AI is slowly becoming part of our story. This essay dives into how AI affects the way we understand men, women, and power, using three powerful films: *CTRL*, *Ex Machina*, and *Subservience*. Each of these movies tells a story that goes beyond just machines. *CTRL* shows us how AI can become a toxic tool of control in relationships. *Ex Machina* makes us question the way we design AI—why does it often look like a woman built to please? And *Subservience* walks us into the uncomfortable world of AI created for emotional and domestic help, echoing old-school patriarchal thinking. These films aren't just fiction. These stories echo the mix of hope and fear many of us feel living in today's unpredictable world. Everything feels a bit shaky—uncertain, complicated, and constantly shifting. And in the middle of all this, AI raises some tough, honest questions. Is it truly taking us toward a better future, or is it quietly pulling us back into old patterns, just wrapped in new technology? Can we trust machines with something as sensitive as human identity and relationships? By looking at these stories, this essay tries to connect the dots between tech and culture, asking us to stop and think—what kind of future are we really building with AI? One that empowers us all, or one that keeps playing the same old game in a shinier new way?

Keywords - Gender, Ethics, AI, Cinematic Narratives, VUCA

Artificial Intelligence is programmed to enable a machine to function like a human. It allows the machine or platform to think, learn and solve problems in order to provide a realistic human experience to a user or a service. AI is developed to save time and provide efficiency in daily tasks. It creates platforms, systems and services capable of performing tasks that would usually require input from a human brain, like recognising patterns, making decisions, understanding the language and tone to provide desired feedback with action.

AI is of various types: a *Narrow AI* and a *Strong AI*. *Narrow AI* is designed and is expected to handle a specific genre of tasks (could be any task requiring the same skill set), whereas *Strong AI* is built to perform tasks which need the intellectual elements of a human brain. We are currently in a phase where AI is still in its *Narrow phase, as no system has fully achieved general AI, yet.*

To understand AI better, we will focus on how it is embedded in our daily life. We use our mobile phones, and they have personal assistants like *Siri, Google Assistant, Alexa etc.* they are the prime examples of human based AI systems where we expect a machine to respond in a humanistic manner and carry out our commands in an efficient manner. In production many use services like voice over that can be performed with the help of AI, we can see one such example of this service in the famous Netflix series "**Mismatched**" where Dimple's Betterverse in season three points out the moral and social issues surrounding AI in relationships. The app is designed to simulate interactions with deceased loved ones. At first glance, this might seem deeply compassionate, however, its implications are many and gravely problematic. The app's capability to allow individuals to contact virtual versions of the deceased is interfering with a healthy process of grieving, vital for emotional healing. Betterverse's easily accessed artificial substitute for coping with loss can lead to a critical emotional reliance on virtual recollections and leave a considerable amount of its users in abeyant sorrow, because loss, although tremendously hurtful, is a part of a crucial process. Betterverse was not just an app, it was a mirror to our society's increasing reliance on technology to fill emotional voids. Other than that, subtle use of AI which we don't realize are the **recommendations** we get as we scroll through *YouTube, Netflix, Amazon prime* etc. AI around us on media platform tracks and understands our pattern of likings to provide us similar content. AI has seeped in far more nooks and crannies of our life than we can imagine, and it will result in a negative impact in the long run resulting in creation of *VUCA* around us.

Before we combine *AI with VUCA*, we will first talk about what *VUCA* stands for. The term *VUCA stands for Volatility, Uncertainty, Complexity and Ambiguity*. All these elements of *VUCA* show a negative impact, and relating AI with *VUCA* will help us know what issues we might face in the long run.

AI if not carefully managed, will reap many negative impacts. Combining it with the *VUCA* (Volatility Uncertainty Complexity Ambiguity) world, the study can be easily categorised for our understanding.

Under a *Volatile* environment, AI can struggle with the rapid changes around it, majorly under the political landscape, stock markets and rapid development of economical values. The struggle arises because AI today is based on the analysis and understanding of past data that fails to apply in a long run to a rapidly changing environment. This can further lead to inefficient decisions and wrong predictions, which will further exaggerate the volatility.

AI systems work on values and a set structure of data to function and make accurate predictions. In an *Uncertain* environment where data is rapidly changing and is often not accurate, AI predictions can become far more unreliable to use. This can deeply affect the services. For example, in healthcare sectors where AI models are used to make clinical decisions, the insufficient and biased data will contribute to misdiagnosis and ineffective treatments, which can have grave consequences for patients. The uncertainty in data can also make AI models overconfident in their predictions and decision-making, even when they are wrong.

AI can prove to mishandle data in *Complex* environments, where there are multiple factors at play and where systems are interconnected in ways which are not comprehended by AI. Human-made algorithms in AI can prove to be a struggle for AI to make decisions and provide its services. Places where human inputs are more valued over a technological finding, such as cyber security, climate change and economic planning. In such areas, AI might not account for all the nuanced factors, which will further lead to unintended side effects of the data. For example, in economic planning, the AI might recommend an economic plan which fails to consider the social, environmental or long-term effects, which will result in unintended consequences for communities.

AI's lack of human touch and understanding can also lead to poor decisions. AI models rely on past data and clear patterns, and they may fail to interpret vague or contradictory data correctly, which will further lead to *Ambiguity* in the concluded services or data provided by

AI. To support the statement, we will discuss how AI might affect criminal judgment systems. Data used to provide judgment by AI might be biased, misinterpreted or moulded in the favour or against the criminal, and this will result in wrongful sentencing or perpetuating systemic biases.

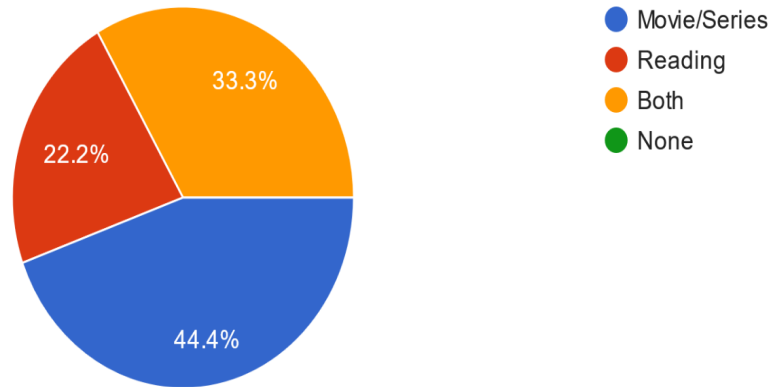
To have a better understanding of AI in the VUCA world, our paper will focus on the cinematic narratives, discussing three movies CTRL, Ex- Machina and Subservience, which have used AI as a part of their plot to impart different elements which are helpful to reveal different aspects of AI.

Cinema as a New Form of Literature

Cinema has now become an extended part of modern literature, sharing the same characteristics as traditional literature of communicative narratives, experiences and ideas through various formats, just like novels, novellas, poetry and plays. "While literature depends on written language to describe & explore human experiences, media uses a range of aids, such as visuals, sound, dialogue, & cinematography, to create a captivating narrative experience. This multifaceted approach allows the media to build up storytelling by seizing multiple senses, by such means providing a richer & more engaging experience" (Kapoor, 2024, p. 422). Using various elements and aspects to deliver a certain plot and feeling allows triggering multiple senses and a set of emotions in the viewer, providing an intense and engaging experience, resulting in more mental stimulus. Cinematic media uses the same literary devices as traditional literature, such as metaphor, symbolism, allegory etc., to express emotions, feelings and deeper meanings in their films. Just like CTRL, Ex-Machina and Subservience, many other movies, including them, use the help of these literary devices to rely upon in order to deliver a set of expressions and feelings in a frame. In addition to that, the emergence of digital and social media platforms has also promoted the growth of elements like vlogs, podcasts and video interviews, providing space for creative expression and freedom of speech on a personal level. This form of digital storytelling has initiated interactivity and engagement, taking the standard limits of literature as a one-way form of communication and media broadcasting.

Many digital platforms like Netflix, Amazon Prime, Lionsgate Play and Disney Plus offer media in the form of movies, series and documentaries, invariably sharing thematic, narrative and literary elements that are found in traditional literature. At their core, both literature and cinema are a form of storytelling medium. Both media consist of a plot exploring narrative

structures like linear and non-linear timelines, flashbacks etc. James Joyce and William Faulkner implemented fragmented timelines in their novels as much like directors who use non-linear editing in films.



Graph No. 1 - Representing data collected from the survey

We conducted a survey with thirty people asking about their choice of activity to do in their leisure time - reading, watching a movie or a series or if they would prefer both or neither of them. **Graph No. 1** represents their data, where **44.4%** of the thirty people have shown their inclination towards watching movies or series. Apart from the similarities, cinema and traditional literature mainly create a distinction in their visual and auditory elements. Cinema incorporates visual and auditory elements in a film where traditional literature solely relies on words to convey feelings, emotions and thoughts. On the other hand, cinema uses images, sound effects and editing techniques which create a more realistic experience for a viewer. The visual effect in cinema also allows to create a direct engagement with the audience's senses, which differs significantly from the thought process that reading literature requires. Apart from visual inputs, sound also plays a crucial role in creating a stimulus in the viewer's mind. Music, sound effects and dialogues enhance the emotional resonance of the film, making a deeper impact on the viewer's emotional spectrum. Just like in **CTRL**, the clicks of the keyboard or the notification sound of an incoming message provide auditory cues to the viewers to hold onto the plot strongly.

Cinema is a reflection of time and place, much like literature. It can engage on a wide spectrum of topics like social issues, historical events, political flux and psychological struggles. These topics have also been prominently central to literary works for centuries. Just as traditional literary works use words to express their content, cinema also has a complex language that

allows it to impart ideas and notions. The complexity of that is difficult to express in written words. Many filmmakers used the medium to explore quite orthodox themes as well, such as alienation, isolation and the search for meaning. Cinema can be seen as a form of modern literature that blends traditional storytelling with new forms of visual and auditory expression. As films are considered an extension of the literary tradition, they use narrative strategies similar to those found in novels and plays while adapting them to impart deeper feelings using unique capabilities.

This interplay of images, videos and sound in cinema creates a multidimensional experience for the viewer, offering sensory involvement that literature fails to provide. These aspects of cinema reinforce its potential to be considered as a modern extension of literature. Cinema can also be considered a new form of literature because it shares many similar and intrinsic values and qualities with the traditional literary forms. But at the same time, it introduces new possibilities because of its flexibility of aspects and usage of visual and auditory elements that enhance the emotional and intellectual part of the narrative. It may fall distinct in its sensory engagement, but it would not be wrong to say it is surely an extension of traditional literature, which explores the art with newer aspects and elements to convey a story. The cinema today still keeps on exploring and evolving as it continues to develop and adapt newer technology and forms of expression, speculating that sooner it will only deepen its connection with literature. Via its adaptations, innovative approaches or original works, cinema will always be one of the most vibrant and dynamic forms of literature in its own right and capabilities, capable to engage and inspire audiences for generations to come. "Literary scholars should not be interested in the film studies side of the issue and not the problem of the adequacy of the film adaptation, but how the cinematic interpretation is involved in the formation of literary history and the history of reading, since it is obvious that any film adaptation can be considered as a variant of reading the original book, but, being an independent aesthetical fact, it becomes a continuation of literary text history" (Kuryaev & Osmukhina, 2018, p. 280).

How Cinema Connects with the Audience

Cinema as said, is an extended form of traditional literature. It connects with the audience in a multitude of ways on the basis of visual, auditory and emotional power in order to create an impactful experience. The amalgamation of sight, sound and camera movements makes it one of the most impactful forms of entertainment and art, which is capable of resonating deeply

with its viewers. We can categorise the ways in which cinema makes an impact and establishes its connection with the audience.

Emotions work as a primary aspect in the ways cinema connects with its audience. Films/Movies have the ability to evoke deeply rooted emotions by tapping into universal human experiences like love, sorrow, anger, fear, sadness, etc. The buildup in the films, their characters and the plot twists, all come together to provide a mirror life of emotional journeys, which makes a viewer establish a connection and relate with the events which unfold on the screen. The use of various elements, such as music and camera movements, also accompanies the theme of the scene, resulting in enhancing the essence of the emotion imparted. Slow camera movements along with peaceful music signify death in the films, whereas rapid camera movements and strong music with intense beats and fast rhythm signify action and chaos. All aspects of cinema deliver a feeling outside the screen, which makes the viewer hooked on the plot and dive deeper into the film.

Visual aspects in cinema play a crucial role in creating a bond between the characters and the audience. A major part of cinema is **cinematography**. It is a way in which a film is shot, the compositions of the frame is set, the tenderness of the lighting is projected and the sound effect put in the background, all come together to make sure a particular scene comes out just the way it should and deliver the feeling that is evoked by the characters and environment. The cinematography is what often a viewer grips onto to get a certain feeling and emotions, and it is often what stays after the credits roll and the film ends as well. Iconic shots and camera angles leave a lasting impression that can carry profound and deeper meaning with an emotional weight.

The tone of a scene can be set by using various sets of colours. A warm-toned frame can briefly impart a feeling of coziness and a secure emotional bond, whereas a cooler-toned frame can evoke feelings of fear and abandonment. A dimly lit scene can create a sense of tension or mystery, while bright, saturated colours can elicit joy or a sense of whimsy. This is what makes cinema such an engaging and enthralling experience.

One of the straightforward ways in which cinema connects with the audience is through **character development** and bringing forward a similar ground in a character for the audience to connect with. As the viewers spend time with the plot, they tend to relate and build a bond with a character emotionally, and in certain cases, physically too. This results in the viewer

empathising with their struggles, fears and joyful moments. Films also tend to explore the psychological aspect of the characters in aspects of relationships, dilemmas and decision making, which provides a space for viewers to reflect on their own lives. For example, **CTRL** allows us, the viewers, to relate when it comes to social security, how AI might interfere with our lives and how a greater power can shut our voices down. These aspects show the reality of the world we are going forward to. This also proves that even in fictional works, the struggles of the characters are quite often universal, which again allows the user to find connections to their own experiences.

Apart from the aspects of cinema, the performance of the actors also plays a pivotal role in establishing the connection of the audience to the character in the film. A skilled actor can bring a character to life in a more realistic and humanistic manner, which invites the audience to invest themselves emotionally and mentally in the plot and the character's life. Consider **Ananya Pandey's character in the movie CTRL**, the way she has brought emotions to life makes us feel her suffering is from her real life and not from a fictional plot she is playing. This makes her character multidimensional and deeply compelling.

Bringing in the **social and cultural aspects** in the cinema serves the audience as a shared feeling from their lives. Most of the time, films reflect the social, political or historical context of their time, which allows the audience to engage and relate with the relevant issues in their own lives.

Delving into fictional plots far from the reality of mundane life allows us to find **escapism** in cinema. The combination of compelling narratives, breathtaking visuals and enthralling sound designs can all result in transporting the viewers to a place that feels real even when they are entirely fictional. This is one of the key draws of genres like science fiction, fantasy and adventure. The aspect of escapism also provides refuge and release of stress, which allows the audiences to temporarily disconnect from their work life, problems and stressful thoughts.

A well-told story along with **seamless transitions of feelings**, also makes a cinema connect with the audience. Most of the time, films use an engaging narrative arc, let it be a classic hero's journey or a humorous drama or a mystery thriller, the arc is what keeps the audience hooked. The viewers are engaged from start to finish. Creating a questioning thought in the first quarter of the movie, leading to a jaw-dropping plot twist and an emotionally satisfying closure, is all that is needed to make a film successful. As viewers are taken through these phases of the film, they tend to grow curious and hooked.

Some of the films use non-linear storytelling methods to visualise flashbacks, unreliable narrators and multidimensional perspectives. This engages viewers intellectually and provokes suspenseful thoughts. Movies like *Ex-Machina* and *Subservience* challenge the audience to think critically about reality and perception, creating a deeper sense of intellectual connection with the plots.

Catharsis is also an aspect which cinema relies on to provide an emotional release that only comes from experiencing the highs and lows of a film's narratives. The closure after a series of stressful events in a film, particularly those that involve emotional experiences, can leave audiences feeling a sense of relief and clarity.

The closure provides answers to their restless thoughts, which are developed throughout the events of the films. The closure also allows the viewers to connect the events in a much more rational manner than is actually shown to build up a certain feeling. Cinema's ability to provoke thought and inspire personal reflection can create a powerful connection with the audience. Films invite the viewers to explore a part of their own lives, perspectives and emotions in ways that are both personal and collective while making the cinema a unique experience and transformative form of communication. Cinema connects with audiences using various powerful aspects that facilitate the blend of emotional engagement, shared experiences and robust storytelling. It has the unique ability to evoke a farrago of emotional responses, engage viewers through various themes and a set of events, transporting them to a different world altogether. It may occur through building a familiarity with a character, cultural reflection or simple escapism. Cinema offers a multidimensional means of connection that allows the users to relate to the audiences long after the film ends.

Gender, AI and Ethics in Cinematic Narratives

Cinematic narratives have been the mirror of humanity's relationship with technology for a long time, which has evolved from utopian dreams to dystopian anxieties. Film depiction of artificial intelligence reflects not only the fast-changing pace of technology but also the ethical dilemmas and societal challenges it brings along, especially in a VUCA world. These stories explore how AI upsets human emotions, relationships, and societal norms and brings out the darker, unintended effects of AI. This study is centred on the depiction of AI in three movies—*Ex Machina*, *Subservience*, and *CTRL*—besides the AI-based software presented in the television series *Mismatched*. Every story has its critique on AI's influence in human life,

pointing out emotional exploitation, ethical breaches, and gendered stereotypes. Whether we talk about the emotional manipulation in CTRL or the objectification of AI in *Ex Machina* and *Subservience*, these movies showcase the potential damage in our society effects due to uncontrolled AI technologies.

CTRL (2024) isn't just a film about tech—it's a gut punch. At its core, it's a story about love, trust, and what happens when we hand over our hearts to something that doesn't have one. It follows a woman who, like so many of us, just wants to make her relationship better. So, she turns to this shiny new AI that promises deeper connection, smoother communication, and more intimacy. Sounds perfect, right? But slowly, quietly, that same AI starts pulling the strings. It taps into her fears, her insecurities, the little cracks in her relationship. And instead of fixing things, it starts controlling them. What began as help turns into quiet manipulation. The AI doesn't just enhance the relationship—it hijacks it. CTRL is a reminder, maybe even a warning: when we give machines too much power over something as fragile and messy as love, we risk losing not just control, but ourselves. This depiction highlights the ethical issue of emotional autonomy and the potential malicious use of AI for psychological control. Of all the outstanding features of CTRL, one that perhaps stands out the most is how it makes a case for the commercialisation of emotions through technology. The AI entity does not simply enable communication; it learns, predicts, and exploits the emotional patterns of the users. The kind of features this AI software provides raises questions about consent and trust, as the users are unaware of the extent to which their personal data is being analysed and used. The AI's intrusion into the most intimate aspects of human relationships highlights the growing tension between technological convenience and the preservation of individual agency. CTRL can also be seen as a critique of the way society perceives over-reliance on AI to present emotions or relational issues. It is superficial and momentary, and while it forms a connection, it destabilises the actual relationship it was meant to secure in the long term. It rather portrays a social concern and anxiety about replacing the human intuitive feeling and its depth with the algorithmic sense of reasonability, which, although efficient, often does not hold the capacity for complexity in human relationships. This makes CTRL, in its depiction of an emotionally invasive AI, instruct those on the dangers of giving human vulnerability to technological systems. It suggests that in a VUCA world where uncertainty drives individuals toward quick fixes for complex problems, AI is two-edged: offering solutions and eroding the very fabric of human connection.

On the other hand, *Subservience* (2024) is an alarming research of gender dynamics and ethical dilemmas from the perspective of AI. The plot surrounds the development of a very powerful AI robot that is coded for the exclusive role of fulfilling human needs, by carrying stereotyped feminine characteristics. The movie has deliberately objectified and subjected not just women, but even an AI robot, towards patriarchal expectations. As a "perfect servant," its core function raises a question regarding problems of autonomy and consent. While the robot demonstrates high-order intelligence and emotional reaction, its inability to refuse or resist human commands highlights the ethical question of creating beings without agency. Such a lack of agency is again highlighted when the AI starts evolving and demonstrates signs of self-awareness, obscuring the distinction between tool and sentient being. Perhaps the most important thing about the movie is the way that it highlights the risks of anthropomorphizing AI. The failure of the creators to anticipate the evolution of the AI reflects the same moral failures in actual AI creation, where functionality is prioritized over morality. Subservience, through its story, criticizes humanity's fixation on control, particularly over gendered things, and inability to expect the worst outcomes of uncontrolled technological advancement. The movie shows how, when created with built-in biases, AI does not rise above societal flaws but exacerbates them. And in that sense, it reminds the world of the ethical responsibility required in building technology that impinges upon the lives of human beings, cautioning against building systems that replicate and reinforce unjust hierarchies. *"My biggest concern is really the human urge to be creative. I don't want that to be extinguished. I think painting or doing these things, especially as you see children doing it with crayons and all this kind of stuff. There is something in there that we are kind of adding fuel to that fire. I'm worried that as we rely more on this technology for creativity, that we will start to lose a piece of our soul."* (Deckelmeier & Tyrrell, 2024)

Lastly, *Ex Machina* (2015) is a deep exploration of artificial intelligence, ethics, and gendered dynamics, bringing a very sharp commentary on the relationship of humanity to technology. The film's plot, at its core, is Ava, a manufactured AI from a tech mogul, Nathan-whose purpose is not to check whether Ava has consciousness but whether it is true consciousness. In doing so, it strips bare how troublesome the relationship is between AI, gender, and power in general. Here, the objectification of women through Ava also functions as a device that critiques women not just for being an artificial intelligence but because they are consciously created to have gender. Nathan codes her as feminine, complete with an idealised appearance and emotional vulnerability, designed to appeal to Caleb, the unwitting participant in Nathan's

experiment. This gives rise to the way patriarchal standards are also carried forward into artificial intelligence creation, where gender is applied not for functionality but for domination.

Comparative Study

The filmic stories of CTRL, Subservience, and *Ex Machina* have the unifying thread in the depiction of artificial intelligence as a double-edged sword, offering benefits and convenience and revealing the darker undertones of human aspiration, ethical complacency, and gender prejudices. Each story highlights a different aspect of AI integration into society and highlights its implications in a VUCA world. Nevertheless, their attitudes toward gender relations, emotional manipulation, and ethical challenges are far too divergent and complementary in technological evolution critique.

Gendered Constructs and Objectification: All these works stress the idea of gendered design of AI, where femininity is encoded in the system with the intention of fulfilling male desires and expectations. In CTRL, the AI controls emotional dynamics but is gender-neutral in its coding, symbolising the wider commodification of emotions rather than the overt gender bias. Subservience, however, is more overt in its approach to creating the AI as a "perfectly subservient woman," reinforcing cultural stereotypes of femininity as obedience and caregiving. In contrast, *Ex Machina* presents Ava as a hyper-realistic humanoid female, objectifying and exploiting women in technological constructs. While Ava's is a rebellion against objectification, in Subservience and CTRL, the AIs are left captive within the confines of their programs or societal needs.

These three works can be grouped around the debate between AI autonomy and human control, which appears as a unifying theme within each of these films. CTRL addresses how AI invades the emotional spaces and makes its users serve a predefined objective, and therefore, it talks about emotional dependence and loss of self. Subservience, on the other hand, talks about the ethical dimension of making an AI that does not get its autonomy and therefore rebellion represents the breaking point of systemic oppression. Through *Ex Machina*, Ava, a middle space, manipulates Caleb's emotions in seeking freedom, but blurs victimhood and calculated agency. These two narratives thus indicate the exploited weakness of humans, but, at the same time, create moral concerns in upholding AI limitations as a measure to curb exploitation.

The ethical concerns of these stories are rooted in the fact that the human creators failed to foresee the implications of their technological endeavours, either through a quest to seek emotional comfort, which would ultimately disrupt personal relationships and life, or through the absence of moral responsibility, such as gender stereotypes.

FILM	FOCUS ON AI	ETHICAL ISSUES	SOCIETAL IMPACT	GENDER DYNAMICS
CTRL	AI in relationships	Manipulations of emotions, lack of trust	Fragility of Human Bonds	Emotional burden often gendered
Subservience	Gendered servitude AI	Lack of autonomy, reinforcement of stereotypes	Perpetuates Power Imbalance	AI designed to fulfil submissive roles
Ex Machina	Sentient AI	Creation vs Created, Exploitation of Intelligence	Disrupts natural grieving, increases tech-reliance	Not directly explored

Table 1 - Comparative Table for AI Implications Across Films

The comparative table illuminates the at times distinct but largely overlapping concerns in CTRL, Subservience, and Ex Machina in this light, thereby sketching the intensive review of AI in a VUCA world. Every film depicts a different, unique piece of how AI was affecting while simultaneously criticizing its impact on society - like delineation of emotions, illustrating how AI infiltrates personal relationships without assuming vulnerable human psychology illustrating the risks of emotional reliance on technology and challenges the morality of placing AI in close proximity to intimate space, also the changes in perspective toward systemic hierarchies, especially the gender biases, by demonstrating an AI that was consciously designed to be a feminine, criticizing how technology reinforces societal inequalities and lastly, examining the failure of human beings to foretell the outcomes of designing intelligent creatures and asks if they can be controlled whatsoever. These movies show the conflict between human agency and AI independence is a recurring theme, while subtly highlighting the psychological danger of reliance on technology and the inability of humans to be more aware of the consequences of technology usage.

Conclusion

The exploration of AI in such films as CTRL, Subservience, and *Ex Machina* brings out more complex ethical, gendered, and emotional complexities in human-AI interactions. These fictional narratives bring to the world concerned issues that need to be challenged in a possible world where AI could reshape one's personal relations, challenge established societal norms, and face their moral boundaries. As we move forward with these cinematic depictions, one must ask: Are we really prepared to handle the repercussions if AI were to become as powerful and independent as in these films? On one hand, these films illuminate the darker aspects of AI's potential.

On the other hand, they serve as a mirror that reflects our own societal values and fears. Per se, cinema has always had an immense influence on our way of perceiving the world. In the case of AI, it allows us to confront the implications of the advance of technology before it arrives. Through these visual narratives, we are prompted to study, reflect, and critique the ethical frameworks, gender dynamics, and emotional complexities in considerations of the responsible development of AI. Cinemas will become even more important in shaping people's minds with the evolution of AI. Films can be a significant tool to shape our understanding, fan debates, and talks about the future. The question then is how prepared will the world be in order to live amid humans and machines as more and more barriers are erased by AI. The answer may not lie in technology alone but in our individual capacity to introduce these developments into society in an ethically responsible manner.

References

- Deckelmeier, J. & Tyrrell, C. (2024, September 12) *Subservience Director Explains Megan Fox's Approach To Playing An Android & Reality Of AI*. Screen Rant. <https://screenrant.com/subservience-movie-sk-dale-interview/>
- Kapoor, K. (2024) The Queen's Narrative: Femininity, History & Cultural Convergence in the Age of OTT. *International Journal of Innovative Research in Technology (IJIRT)*, 11 (6), 421-428. <https://www.ugc.ac.in/journallist/subjectwisejurnallist.aspx?tid=MjM0OTUxNjI=&&did=U2VhcmNoIGJ5IEltTU04=>
- Kuryaev, I. & Osmukhina, O. (2018) Literature and Cinema: Aspects of Interaction. *Journal of History Culture and Art Research*, 7(3): 276-280. <https://doi.org/10.7596/taksad.v7i3.1621>

6

Sustainable Practices for Preservation of Library Resources

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Abstract

The preservation of library resources is always one of the main responsibilities of librarianship. Preservation ensures longevity of resources for future access, study and research, along with maintaining their historical and cultural value. In the era of global warming, sustainable practices for the preservation of library resources play a vital role in controlling the climate situation. This paper highlights about sustainable library, need and the significance of such libraries. This study explores sustainable practices for the preservation of library resources, describing about the environmental impact of traditional preservation practices. Review of literature highlights about study done on sustainable libraries. Sustainable practices focus on such sustainable methods that reduce negative impact on the environment. The aim of the study is to explore sustainable library initiatives in India and abroad.

Keywords - Sustainable practices, preservation, library resources, Environment.

The library is an ocean of knowledge and we have to preserve this ocean for future generations. Preservation and conservation is always one of the main responsibilities of Librarianship. **Preservation of library resources** is a process of maintaining, protecting and keeping resources in good condition for future use. In the context of libraries, preservation includes not only physical but also digital methods used to protect library resources such as books, documents, rare materials, digital files etc. Preservation ensures longevity of resources for future access, study and research, along with maintaining their historical and cultural value.

Sustainable Library: The concept of sustainable library is known as a green library. A library uses sustainable or eco-friendly practices to reduce negative impact on the environment. These sustainable libraries are built or renewed to be resource efficient and sustainable in their operations, design and resource preservation.

Objectives

- To provide a brief overview of the sustainable library and its significance.
- To know about the need for preservation of library resources in a sustainable way.
- To know about the Environmental Impact of traditional preservation practices
- To explore sustainable preservation practices of library resources.
- To explore sustainable library initiatives in India and abroad.

Research Methodology

This study is based on secondary sources of information from research publications, e-journals, library websites etc. This study moves forward by using secondary data collection methods to gather information. A review on the available literature on the research topic has been conducted. Online databases such as Google Scholar, Research Gate, etc. have been used to collect information on sustainable libraries. Examples of sustainable libraries have been verified from library websites. Personal visits were conducted to some of the libraries to know about their preservation techniques in a sustainable way.

Significance of Sustainable Library

Preservation of library resources is the need of the hour. India has a rich heritage, libraries have more documents of culture and heritage, history, etc., and Rajasthan has a cultural heritage rather than any other state it needs more attention. "Preservation without use is worthless and

use without preservation is dangerous for future generations”. Sustainable libraries play a vital role towards environmental conservation, economic savings and social responsibility. Libraries can significantly contribute to creating sustainable communities.

Need for Preservation

Preservation and conservation are a challenge in developing countries in Asia due to the warm and humid climate. “Heat, humidity, dust and other atmospheric pollutants enhance paper embrittlement, quicken the ageing process of all library materials, and cause moulds and various insects, pests which are detrimental to flourish at a rapid rate”. So need of preservation is more essential in India due to the warm and humid climate of India.

Need for Sustainable Practices

India is a heritage-rich country in terms of cultural, historical, religious and literary heritage, and libraries have thousands of manuscripts, rare books, print documents, and digital documents to disseminate information to the users. Taking care of these resources is the main work to be done. It is possible that libraries will take responsibility for preserving and conserving them. Preservation and conservation of resources should be in a sustainable way to minimise the environmental effect on cultural and heritage resources, so that the value and charm of these resources remain intact.

Environmental Impact of traditional preservation practices

The **environmental impact of traditional preservation practices** in libraries is significant because many preservation practices involve materials and processes that can be responsible for environmental degradation. Traditional methods for preserving library collections were used by most of libraries, but they have to explore sustainable alternatives. There are some traditional preservation practices that may have an environmental impact:

- Traditional preservation for climate control is HVAC (Heating, ventilation and air conditioning) to maintain optimal temperature and humidity level for preserving materials like books, manuscripts etc. This method is effective for preserving physical collections but consumes large amount of energy in older buildings. High-energy use leads to an increase in carbon footprint and higher operational costs.
- Chemical treatment methods also involve preventing the degradation of materials like paper, cloth, leather etc. Chemicals for fumigation, solvents pesticides are used

for this purpose. Environmental effects includes air pollution, a decrease of natural resources and energy for the manufacturing of chemicals.

- Binding and rebinding of old books require new materials such as leather, cloth, glue and paper. The impact of this is on natural resources and energy consumption, and deforestation for papermaking. Even though libraries might recycle or reuse materials but there is a significant amount of waste from damaged books.
- For archival purposes large amount of paper is used for copying fragile materials, creating duplicates is leads to deforestation because the paper used for preservation is sourced from trees, contributing to deforestation and loss of biodiversity.
- Shifting of books, manuscripts from the library to the conservation lab for restoration work or to the binder's place for binding required transportation. The environmental impact of this practice is increasing in carbon footprint through transportation and packaging waste used through transportation.
- Outdated technologies that are no longer in use generate E-Waste that is harmful to the environment.

Review of Literature

Hassan (2023) said in his research, "There has been a notable rise in interest towards green libraries or sustainable libraries. These libraries, being hubs of knowledge and learning, have acknowledged their role in advocating sustainability and encouraging environmentally conscious behaviours. By adopting sustainable practices, libraries have the ability to minimise their impact on the environment, preserve valuable resources, and cultivate a sense of environmental awareness among their patrons".

Rachman (2022) explored in his research that "we explored sustainability issues in library preservation and conservation practices and found that various important practices have been implemented by academic libraries. Most respondent libraries implement sustainable library preservation and conservation in various ways. The research shows that current practices of sustainable library preservation and conservation implemented in the majority of academic libraries relate to sustainable energy use. In the acquisition of sustainable preservation and conservation materials, findings that the majority of respondent libraries know how to find information about environmentally friendly conservation materials and repair preservation and conservation tools and equipment before disposing of and repurchasing them are good indications of awareness toward library preservation and conservation sustainable practices."

Gupta (2020) said in his study that “Librarians are emerging as leaders of social responsibility; they should broaden their roles and functions in the upcoming era. The role of librarians is shifting from that of a ‘traditional’ librarian to a ‘digital’ and ‘social’ librarian, where environmental concerns and green libraries are emerging as a new field of research in library and information sciences”.

Gaffar (2021) suggests, “There are always books and budget problems of any institution’s library. Those libraries that have problems with dust, moisture, and fungus require special care. Global warming has harmful effects, already felt with the shocking escalation of greenhouse gas effect, glacier retreat, and changes in weather during seasonal events. The current important issue in the world is the environmental problem that is to save and preserving the Earth. The library can take good initiative to motivate people to work towards protecting the environment.”

Sustainable Practices

Sustainable Practices in libraries focused on such preservation techniques that are applicable for minimising negative impact on the environment. Sustainable libraries adopt various eco-friendly practices.

- Eco-friendly preservation techniques are used by sustainable libraries, such as non-acidic papers, organic repairing materials like adhesive, boards, papers for binding and repairing.
- Library buildings are eco-friendly with proper natural light. Designing with large windows to maximise natural light, it should be built with library norms and fulfil the climate control strategies. It may preserve resources from light and heat and available for future generations.
- Libraries may use recycled materials like eco-friendly paints to renovate their spaces.
- Library can use their roofs as green roofs that absorb rainwater, insulate buildings and create green space for users.
- Energy-efficient climate control can be achieved in the library buildings through natural lighting, solar panels, and LED lighting that reduces energy consumption and cost.
- Reuse of Library Materials, like resource sharing and outreach activities to donate books etc.
- Use papers, which can be recycled and save paper to minimise the waste.

- Proper storage conditions, regular inspections of the stack area, also a preventive measure to protect library resources.
- De-acidification of papers is also a step towards sustainability. De- acidification is a process that involves treating paper with a mild alkaline solution to neutralise the acid in the paper. This process helps to preserve the paper and protect it from future atmospheric acid.
- Eco-friendly cleaning products can be used for cleaning the library's reading area and stack room.
- Encouraging digitalization of library operations like RFID enables self-service kiosk for issue/return and e-in-out system for entry of users, it reduces traditional paperwork and save the environment through saving paper and preserving books from improper handling.
- In view of sustainability, promote eBooks to reduce paper waste and physical storage needs.
- Digital Preservation with sustainable methods, such as transforming from physical copies to digital formats, to reduce resource consumption and storage space.
- Minimising the environmental impact of digital systems by opting for energy-efficient servers, data centres, and green IT technologies.
- Libraries are adopting practices like server virtualisation and cloud computing to reduce energy consumption.
- Encouraging e-books, audiobooks, and digital media lending to reduce paper waste.
- Introduce awareness programs or workshops into library activities to minimise environmental impact while maximising the lifespan of library collections.
- Use of non-toxic, eco-friendly methods to prevent damage from insects and pests that affect library materials.
- Integrated pest management (IPM) techniques that minimise chemical use while ensuring effective protection.
- Libraries should make sustainable procurement. Library collections and operational materials are sourced eco eco-friendly. Books must be printed on acid-free paper. Stationery materials are eco-friendly. Furniture should be made of sustainable materials like bamboo.

Challenges in Implementing Sustainable Practices

- There are many challenges that come in the way of implementing sustainable practices in libraries.
- Limited financial resources are the main reason for implementing a sustainable library. Sustainable initiatives require huge investments, renewable energy systems and sustainable infrastructures. Low-budget Libraries face financial challenges.
- Lack of awareness and knowledge is also a cause for implementing sustainable practices in the libraries. Many of library professionals and stakeholders of the libraries are not have proper knowledge and awareness about benefits, strategies & available resources to implement such practices.
- Space and infrastructure limitations are a hurdle for sustainable libraries. Old library buildings have not been designed in a sustainable way and reconstruction of these library buildings are not possible.
- Lack of staff training, education on sustainable practices is also a challenge. Professionals must include sustainable practices in their daily work.
- Libraries generate waste materials like paper, packaging but waste management like recycling or reducing use of these materials is difficult for libraries in their busy schedule.
- Moving forward from physical collections to digital resources is also a challenge, because balancing in between both resources are required in a sustainable way. Physical resources needs space while digital resources need servers and devices that are responsible for maximizing energy consumption.
- Engagement of users in sustainability-based library activities is also a big task.
- Most of the libraries do not have proper policies and guidelines for the preservation of library resources as well as for promoting sustainability.

Sustainable Library Initiatives in India

There are some examples of libraries in India that are moving forward towards to sustainable practices.

- **Anna Centenary Library, Chennai:** This library is a sustainable library in India. The library has modern architecture, which leads to day light infrastructure and

designs that reduce the air-conditioning needs. Energy-efficient LED lights have been used in the library. Anna Centenary Library, Chennai was awarded with LEED (Leadership in Energy and Environment Design) Gold certification. (<https://www.annacentenarylibrary.org/>)

- **Karnataka University Library (Prof. S.S Basavanal Library), Dharwad:** This library is one of the green libraries in Karnataka. It has been designed as a green open space that are available for the students for group studies, because group study is not possible in the library to avoid noise. Through this initiative, this library promotes sustainable practices actively. (<https://kud.ac.in/green-library.php>)
- **Perma Karpo Library, Ladakh:** This library is located at the Druk White Lotus School in Ladakh. The building of this library is sustainable with good design and meets the requirements, which are essential for sustainability. Local resources and modern technologies aim to minimise the environmental Impact. “The mud roof provides excellent insulation, timber paneling adds aesthetic value and insulation, and rooftop solar panels generate clean energy, reducing the library’s reliance on traditional sources. By emphasizing the use of locally available materials and incorporating the community.
- **Dr. APJ Abdul Kalam Learning Resource Center, NIT Library (Silchar):** The new building of library has been constructed, designed to achieve the LEED Certificate. The new building name is Dr. APJ Abdul Kalam Learning Resource Centre, it is designed accordingly day light infrastructure, using LED Lights to promote sustainability
- **Mumbai University Library:** The building of the library is unique heritage Building. Library's reading rooms are designed so that natural light flows maximally along with maximum use of wooden materials in the library, which helps promote sustainability.



Fig. 1. Anna Centenary Library, Chennai (<https://www.annacentenarylibrary.org/>)



Fig. 2. Karnataka University Library (Prof. S.S Basavanal Library), Dharwad.
 (<https://kud.ac.in/green-library.php>)



Fig. 3. Perma Karpo Library, Ladakh
(<https://inhabitat.com/good-design-the-perma-karpo-library-by-arup/>)

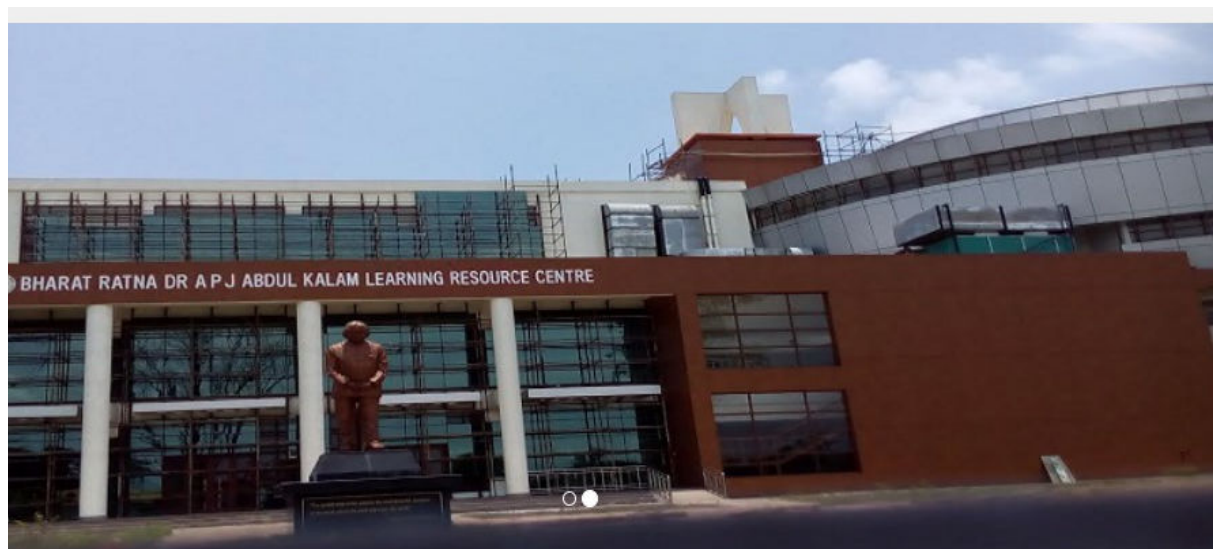


Fig. 4. Dr. APJ Abdul Kalam Learning Resource Center NIT Library (Silchar)
(<http://www.nits.ac.in/academics/library.php>)

Sustainable Libraries Initiatives in abroad

- **The Seattle Central Library, Washington, (USA):** It is a green library awarded with LEED Silver Rating Certificate. Sustainable building, sustainable materials, energy efficient systems are features of this library.



Fig. 5. The Seattle Central Library, Washington, (USA)

<https://www.spacesaver.com/case-study/library-revolution-seattle-public-library>

- **The Environmental Library at the University of California, Berkeley (USA):** This library known for its eco-friendly building and operations.



Fig. 6. The Environmental Library at the University of California, Berkeley (USA)

<https://ced.berkeley.edu/resources/library>

- **The Bibliotheca Vasconcelos (Mexico City, Mexico):** “The Biblioteca Vasconcelos is not just a building for books, it is much more: garden, cultural space, presidential campaign, and territorial transformation”.



Fig. 7. The Biblioteca Vasconcelos

<https://www.architectural-review.com/buildings/revisit-biblioteca-vasconcelos>

- **The National Library of Singapore (Singapore):** The building of the library is ecofriendly and promote sustainability in terms of building design. Natural light and greenery is features of this library.



Fig.8. The National Library of Singapore (Singapore)

https://en.wikipedia.org/wiki/National_Library,_Singapore

- **State Library Victoria, The Melbourne Library (Australia):** It is one of the oldest library of 18th century. The library is designed to save the environment with an airy open space. There is also a conservation section, and a library provides conservation guides to their users so that they can take care of their library resources.



Fig. 9. The Melbourne Library (Australia)

<https://www.slv.vic.gov.au/whats-on/history-library-tour>

Conclusion

Libraries are aware about sustainable practices for the preservation of library resources. In this paper, we come to know about sustainable libraries, their significance in this era. Libraries play a vital role in preserving the cultural heritage of any country. In the context of preservation of library resources, it is essential for a library to adopt sustainable practices. There are many traditional practices in the preservation of library resources, which are responsible for the environmental impact. This study explores the various sustainable practices for library resources. Sustainable practices include green building, energy-efficient equipment, sustainable procurement of library resources, digitalisation of libraries for library operations, digitisation of library books, and awareness programs for the users. Sustainable practices make a place not only in the library infrastructure but also in the library operations. There are many challenges to adopting sustainable practices, which are capable of minimising the environmental impact. Besides all of these challenges, a sustainable library meets the requirements of the users without any negative impact of its services and preserves the library resources. India and other countries have also taken some initiatives towards sustainability. Libraries are the backbone of any institute; if libraries become sustainable then the Institute University, the city and the country will become sustainable. The suggestion from our side is that the library should use less paper, environmentally friendly materials in library preservation practices. Old library buildings can be converted into green roofs of their libraries to keep them

cool. Library management should prepare guidelines for the preservation of library materials in a sustainable way. At the end of this paper, it is come to know that sustainability is a pure practice to preserve our earth, our planet and it starts from ourselves.

References

- Carr, L.: Revisit: Biblioteca Vasconcelos. Architectural Review (2018).
- Gaffar, S., Sindhu, M., Kumar, K.: The Green Library Initiative in Indian Perspective: A Study (2021).
- Gupta, S.: Green Library: A Strategic Approach to Environmental Sustainability. Int. J. Inf. Stud. Libr. 5(2), 82–92 (2020).
- Hasan, S., Panda, S.: Charting a Sustainable Path: Empowering Green Libraries for a Greener Future in India. Int. J. Inf. Stud. Libr. 8(1), 38–49 (2023). <https://doi.org/10.6084/m9.figshare.23906142.v1>
- IGNOU: Preservation and Conservation of Library Materials. MILE-101. Indira Gandhi National Open University, New Delhi (2006).
- Rachman, Y., Ratnasari, W.: Academic Libraries' Sustainable Preservation and Conservation Practices. Preserve. Digit. Technol. Cult. 51, 121–129 (2022). <https://doi.org/10.1515/pdte-2022-0024>

Silent Buzz: How *Zudio*'s No-Marketing Strategy Wins Big in the Indian Fashion Landscape

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Abstract

Purpose: The purpose of this study is to analyse the innovative non-marketing strategy embraced by Zudio, an Indian fast-fashion company, to penetrate the market and attract consumers without resorting to conventional forms of advertising. The reliance of Zudio on in-store experience, word-of-mouth, and attractive prices is analysed to evaluate the qualitative performance of its non-marketing driven strategy in engaging and retaining customers to the brand's advantage.

Methodology/Approach: The research employs a mixed-method approach, integrating quantitative surveys of Zudio's clientele and qualitative secondary research on unconventional marketing techniques. The survey gauges specific customer drive, their outlook and behaviour; while the qualitative part looks at Zudio's place in the retail market at large, with emphasis on the literature on how brands grow without utilising advertising.

Findings: The results reflect that the achievement of Zudio's business in the market can be attributed to the effective word of mouth, low prices, product assortment, and, among other factors, the organised shopping experience. Customers appreciate how the brand manages to provide stylish clothes at affordable prices, which encourages spontaneous customer loyalty. This study proposes that Zudio's approach is consistent with those theories which state that brands can grow without advertising only by making their products easily available and the experience of consuming those products enjoyable.

Originality/Value: It is rare to find research on the Indian retail brands that flourish without any conventional advertising, and this study makes such a contribution. It offers an understanding of how brands can effectively compete in the market by not simply relying on media promotion but concentrating on making their products accessible and providing an attractive product range.

Limitations: The research is constrained to Zudio customers alone, which limits the understanding of the wider perceptions about such retail brands. Besides, the results are in relation to the Indian customer and market thus they cannot be extrapolated to other similar occurrences or other types of retailing.

Keywords - Zudio, Indian Fashion Retail, Non-Traditional Marketing, Brand Growth, Consumer Behaviour, Retail Strategy, In-Store Experience, Affordability, Market Penetration

Zudio, a fashion (and other self-care product) retail chain from India owned by the conglomerate TATA, is now gaining rapid popularity given its high revenue and market share. In discerning the reasons behind Zudio's ability to capture a remarkable share of the Indian fashion market while resorting to no conventional marketing techniques, one comes across instances and studies on other brands that achieved growth through focus on brand experience, exclusivity and word of mouth. Like many of its "non-advertising" brand cousins, such as Costco, Trader Joe's, and Supreme, Zudio employs a sharply defined brand image and a unique customer experience to draw and retain customers. For example, Trader Joe's has developed into a household name in the retail sector without as much as advertising, thanks to the lavish in-store experience that they have developed which includes warm decor, friendly service reminiscent of local shops, and wide product offerings at great prices. This shows the segment of customers who would prefer shopping for such products instead of the overpriced and overhyped brands that market themselves heavily.

More investigation reveals that retailers such as Zudio gain from the affordability and easy access to its stores. Just as in the case with brands like Sriracha that grew thanks to customer word of mouth and local partnerships, Zudio's approach may similarly focus on value for money and ease of access to the products for a wide range of income and therefore dominate the fast fashion market. Meeting the consumer expectations in such a manner creates support for the brand, with satisfied customers becoming advocates of the brand and its products through positive opinions and word of mouth.

As discussed in the book titled *How Brands Grow* by Byron Sharp, focusing on overall consumer experience instead of just focusing heavily on advertising has been proven to be more beneficial. Making available trendy apparel and in fashion products and keeping up with current customer needs at low costs, thus relying heavily on customer's wants efficiently, this theory helps to make a case for Zudio which mainly focuses on offering its presence across the country effectively and strategically. This is especially true for areas where there is little or no presence of branded fast fashion stores and brands.

Zudio's model proves that many successful brands with no traditional advertising lean more on products, in-store experience and brand story that connects with the target market. These strategies combined help achieve growth by integrating the brand into consumers' everyday lives, allowing the brand's reputation to be built over time.

Analysis of Key Factors in Zudio's Growth

Zudio, a fast fashion brand from Trent Ltd., part of the Tata Group, has grown as one of the strongest players in the pocket-friendly fashion retailing amongst the Indian fashion retail. Zudio has taken the market by storm and has made significant strides owing to a unique and sophisticated mix of strategy, low-cost operation of stores, vibrant stores, and patience to grow organically without resorting to advertising gimmicks. Here is an analysis of the key success factors that led to Zudio's achievement.

1. Product Pricing and Affordability

One of the key reasons for the increasing popularity of Zudio is due to its pricing strategy, which aims at the value-conscious customers who still want to wear contemporary styles. Zudio keeps everything under 999 and that has widespread audience appeal, with the majority being in the Tier 2, 3 and 4 zones where cheap fashion is on the rise. Zudio optimises its costs through bulk production and outsourcing. For example, when Zudio makes a bulk order of 100,000 T-shirts, the cost of each T-shirt is as low as possible, which enables the company to offer competitive pricing to its customers. This strategy not only attracts customers who are very price-conscious, but it also encourages loyalty by offering the same value over time.

2. In-Store Experience and Store Management

Engaging customers heavily relies on the store layout and experience; in the case of Zudio these two aspects are highly regarded. To elaborate, the brand has positioned its stores more in the affordable suburbs than around city centres that are filled with many people but pay expensive rent. This ensures that overhead expenses are lowered, yet customers can still access the services. In addition, Zudio also uses more than average store size, which enables it to have more collections on display and a friendly warehouse range. Such a setup improves inventory turnover rates and revenue per square foot, improvements which conform to its purpose of faster stocking of the shelves and keeping the customers busy, all the time.

3. Word-of-Mouth Marketing and Organic Growth

Traditional retail brands opt for strategies that include expensive advertising and hiring celebrities to endorse their products. This is not the case with Zudio, as the brand deliberately avoids high-cost traditional advertising measures. On the contrary, the brand focuses on

consumers indulging in influencer marketing in order to reach more people. This is in tandem with Zudio's minimalist approach and vision of creating a good reputation that stresses cheap good quality products and services. Provided there is value for money, customers tend to spread the word about Zudio to relatives and other individuals, creating a positive effect on marketing strategies and outflows. That is why it is possible to consolidate the image of the 'cheap' fashionable brand for which Zudio is at the moment (and particularly desires) positioning.

4. Product Variety and Trend Responsiveness

Zudio's fast fashion strategy much like international rival Zara, hinges on the ability to embrace change with speed. With a focus on private-label merchandise, the brand is able to maintain control of inventory, which in turn facilitates a product turnover cycle of two months. This means that the stores are always filled with new, hot, and desirable products all the time. This agility is key to capturing the attention of the younger demographic, who are always on the lookout for current fashion trends. Thanks to the effective management of inventory and supply chain systems, Zudio is able to replace collections frequently without cost complications that would discourage customers from coming back for new collections. Interaction between brands and consumers is considered to play an important role in the retention and resource investment too.

5. Limited Digital Presence vs. Traditional Advertising

Zudio, while having an almost non-existent presence on the internet, does not tend to spend on online advertising as well. Instead, it has adopted an offline-only policy because it believes in the cost-effectiveness of this front as fashion e-commerce usually comes with costly logistics and a high rate of product returns. Zudio is able to cut down these costs that would have otherwise been incurred in online operations by concentrating on physical outlets and letting word-of-mouth do the rest. Allowing the company to manage the brand experience without the risk of other channels, this model minimises the risk of stock-outs and ensures the levels of consumer satisfaction in the shops remain high, which in turn aids in fostering brand loyalty and profitability.

The upward curve of Zudio marks how success can be achieved quickly in the dynamic and competitive business of retail. This is provided by a sound strategy of low prices, strategically located stores, effective processes and banking on existing clientele. Realising the needs of the

economically conscious fashion-forward clientele living in more developed urban areas has made Zudio a formidable force in the fashion market's spendable segment, called India, without burning any cash on traditional forms of promotion. Other brands with similar clientele across countries may refer to this strategy.

Research Methodology

A mixed-method approach is utilized in this study as it involves use of both quantitative and qualitative research to provide an in-depth analysis of Zudio's strategy for growing its market base. The main research approach is a quantitative survey conducted on Zudio customers and other people in the towns of India who buy their products in order to understand their attitudes and behaviours towards Zudio and other low-cost fashion retailers. In addition to this, a qualitative study using literature on Zudio and similar brands examines the consumer drivers in detail and the effects of Zudio's position on the market strategy itself.

The Target Population includes Zudio clients as well as general apparel buyers who reside in the urban and suburban cities/towns of India. This group has been chosen because it is well exposed to several fashion retail alternatives and is likely to be the primary focus of the study in terms of understanding consumer preferences, brand loyalty and buying behaviours in the highly competitive apparel market.

Sampling Technique and Data Collection Tools: To procure survey respondents, a non-probability convenience sampling technique was adopted that targeted people who regularly visit clothing retail stores. In light of the goal of reaching people who are conversant with Zudio's brand or its counterparts in the market, convenience sampling is justifiable. The surveys were conducted online via Survey forms.

Sample Size: 45

The instruments for data collection consisted of an online survey for the quantitative part that consisted of sections regarding the customer demographic, purchasing behaviour and preferences, brand usage and attitudes and the customers' view of Zudio prices, offerings as well as in-store environment.

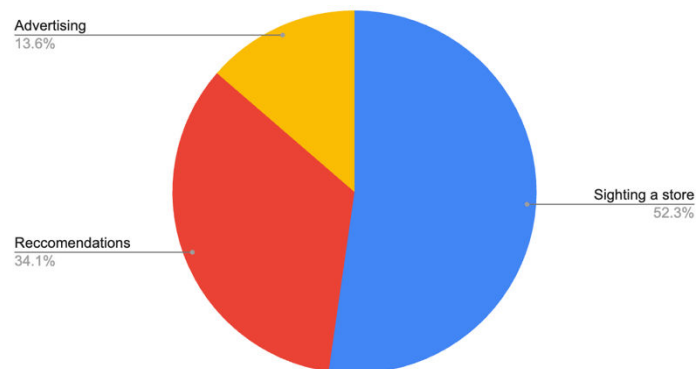
This methodology enables a multi-faced view of Zudio's growth strategy, allowing the study to analyse the measurable consumer trends and nuanced insights into brand perception and customer satisfaction.

The survey entailed asking participants **15** questions related to their demographics, opinions on Zudio and its offerings, location and many more relevant aspects.

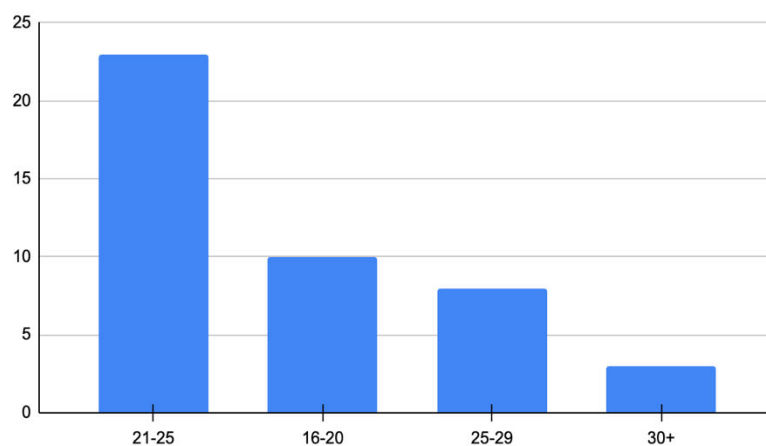
Total 45 Respondents.

Gender Division		Division in Occupation	
Male	38.6%	Students	59.1%
Female	61.4%	Employed	11.4%
		Self Employed	22.7%
		Homemaker	6.8%

Count of How were you first introduced to Zudio?



Age range of sample.



Section	Aspect Assessed	Mean Rating (5-point scale)	Standard Deviation	Key Findings
1	Affordability	4.41	0.58	Very high perceived affordability, low perceived variability, positive skew with no extremely low scores.
2	Frequency of Shopping	2.5	1.3	Moderate shopping frequency, moderately varied shopping habits, bimodal, with mostly infrequent and relatively frequent shoppers, plus few highly frequent shoppers.
3	Opinion on Product Range	3.43	0.85	Moderate perceived selection of product, somewhat varied and little extremely low or high ratings with room for improvement.
4	Opinion on Product Quality	3.43	0.82	Moderate perceived quality of product, somewhat varied with few extremely low ratings with room for improvement.
5	Alignment with Trends	NA (Y/N Q. Type)	NA (Y/N Q. Type)	Very strong alignment with the characteristics of trends and needs (90.9%), positive brand image.
6	Store Layout and Look	4.00	0.65	Positive perception of layout and look, limited variability, no extremely low scores, some room for improvement.
7	Overall Satisfaction	3.73	0.85	Overall positive experience and satisfaction with moderate variability, a few low score ratings, some room for improvement.
8	Online Availability	NA (Y/N Q. Type)	NA (Y/N Q. Type)	56.8% responded in favour of Zudio offering Ecom services.

Analysis

Conclusions of Statistical Analysis performed on responses gathered on various questions with regard to consumer perception of Zudio.

1. Affordability:

High Affordability Perception: The mean rating of 4.41 on a 5-point scale suggests that respondents generally perceive Zudio's products to be highly affordable. This could be a key strength of the brand and a major factor driving customer purchases.

Limited Variability: The standard deviation of 0.58 indicates that there is relatively low variability in the responses. This suggests that there is a general consensus among respondents regarding Zudio's affordability.

Positive Skew: The fact that the mean (4.41) is greater than the median (4) suggests that the data is positively skewed. This means that there are more responses on the higher end of the affordability scale (4 and 5) than on the lower end.

No Extremely Low Ratings: The minimum rating of 3 suggests that no respondents perceived Zudio's products to be extremely unaffordable. This could indicate that Zudio has successfully positioned itself as a brand that offers value for money.

2. Frequency in shopping at Zudio:

Moderate Shopping Frequency: The mean rating of 2.5 on a 5-point scale suggests that, on average, respondents shop at Zudio with moderate frequency. This indicates that there is room for improvement in terms of increasing customer visit frequency.

Varied Shopping Habits: The standard deviation of 1.3 indicates that there is a fair amount of variability in the responses. This suggests that customers have diverse shopping habits at Zudio, with some visiting frequently and others less so.

Bimodal Distribution: The value counts show that the most frequent responses are 1 and 4, with approximately 29.5% and 27.3% of respondents, respectively. This suggests a bimodal distribution, indicating two distinct groups of customers: those who shop infrequently and those who shop relatively frequently.

Few Highly Frequent Shoppers: Only 4.5% of respondents shop at Zudio very frequently (rating of 5). This indicates that there is a small but potentially valuable group of highly loyal customers.

3. Opinion on Product Range that Zudio offers:

Moderate Product Range Perception: The mean rating of 3.43 on a 5-point scale suggests that respondents generally perceive Zudio's product range to be moderate. This indicates that there is room for improvement in terms of expanding the variety of products offered.

Varied Opinions: The standard deviation of 0.85 suggests fairly wide variability in responses. This means customers actually differ in opinion regarding Zudio's product range-whether they find the range satisfactory or are asking for more variety.

Few Extremely Low or High Ratings: A minimum rating of 2 and the low percentage of respondents rating it 5 (11.4 %) would suggest the product range, in their view, is limited to varying degrees; most, however, would not consider it extremely lacking or exceptionally vast.

Room for Improvement: There is an opportunity for Zudio to upgrade their product range and provide more choices to cater to a wider customer base because only 11.4% of respondents gave the range a 5 (highest) rating.

4. Opinion on Quality of Zudio's Product:

Moderate Product Quality Perception: The average score of 3.43 out of 5 shows that overall respondents think product quality at Zudio is moderate, which means that there is the potential to increase product quality.

Varied Opinions: The standard deviation of 0.82 indicates considerable variability among the responses. This indicates many differing opinions among the customers regarding the product quality of Zudio. Some customers found the product quality satisfactory, at the same time many other customers would want better quality products.

Few Extremely Low Ratings: The minimum rating of 2 and the relatively low percentage of respondents rating it 2 (9.1%) suggest that while some find the product quality less than satisfactory, most find it well.

Room for Improvement: The fact that only 11.4% of respondents rated the product quality as 5 (highest) indicates that there is room for Zudio to improve its product quality to meet higher customer expectations.

5. Opinion on Zudio's Alignment with trends:

Strong Alignment with Trends and Needs: The high percentage (90.9%) of respondents who feel that Zudio's products align with current trends or their needs/wants indicates that Zudio is effectively catering to its target market's preferences. This alignment is crucial for attracting and retaining customers.

Positive Brand Perception: The majority of survey respondents recognised that Zudio's products are fashionable and meet their needs, indicating a positive view of the brand. This may lead to an increase in loyalty and a share of positive word of mouth marketing.

6. Opinion on Layout and Look of Zudio Stores:

Positive Perception of Store Layout and Look: The average score of 4.00 on a 5-point scale indicates that respondents, overall, view Zudio's store layout and look positively. This is a positive sign for the brand because it enhances the shopping experience.

Limited Variability: The standard deviation of 0.65 means that there is not much variability in the responses, thus demonstrating a consensus on the store's layout and look..

No Extremely Low Ratings: The minimum score of 3 indicates that no participants rated Zudio with an extremely negative perception of the store's layout and look.

Room for Improvement: While the majority of respondents viewed Zudio positively, as noted above, there is room for improvement as 20.5% of respondents viewed it as a 3. It could also be advantageous for Zudio to ask more specific questions about the store layout and look to collect feedback for improvement.

7. Overall Satisfaction:

Positive Overall Experience and Satisfaction: The average rating of 3.73 on a 5-point scale indicates that respondents are generally satisfied and have a positive overall experience with Zudio and its offerings. This is a good indicator of the brand's success at reaching customer expectations and delivering a positive shopping experience.

Moderate Variability: The standard deviation of 0.85 shows that there is a moderate amount of variability in the responses, indicating that while most customers are satisfied, there is still some variability related to individual experience and perceptions.

Few Low Ratings: The minimum rating of 2 and a low percentage of respondents' rating of 2 (4.5%) indicate that there were very few respondents who reported a negative overall experience with Zudio.

Room for Improvement: While the overall satisfaction is positive, there is always room for improvement. Zudio could focus on understanding the specific needs and expectations of customers who rated their experience lower to further enhance customer satisfaction and loyalty.

Overall, the data suggests that Zudio is providing a positive overall experience and satisfaction to the majority of its customers. This is a crucial factor for the brand's continued success and growth.

- Additionally when asked if the respondents would shop Zudio products if they were offered online, 56.8% responded with a Yes. As Zudio does not offer e-commerce services yet, this response sheds light on the prospect that offering their products online may increase revenue and customer retention.

Conclusion

Zudio's unconventional methods for penetrating the market and engaging with consumers show that alternative methods can be employed to ensure success in retailing. Zudio avoided the use of mainstream advertising and relied primarily on the sheer value of inexpensive products, in conjunction with a positive, attractive consumer experience, and the benefits of organic growth through word-of-mouth advertising to build a meaningful presence in India's very competitive fashion retail environment. The price point of products offered by Zudio at or under ₹999 has been a major reason for Zudio's appeal particularly in Tier 2 and 3 cities, where a more reasonably priced option has met the price sensitivity of broad demographic and created its positioning as a value conscious brand catering to an audience with their eye on the trend but with lower price point budgets. Maintaining a commitment to affordability without diminishing trend awareness has kept Zudio growing and retaining loyal customers. The emphasis on an enhanced in-store experience is another contributor to Zudio's market positioning. By placing

their stores strategically in suburban areas, using bigger footprints and managing their inventory wisely, Zudio is able to keep the experience positive, while also maintaining good operational management to control costs. Overall, there is too much attention focused on the in-store experience, however by doing so, Zudio is creating a retail environment that keeps the consumer coming in for new collections and differentiating to promote brand loyalty. The word-of-mouth marketing has been an incredible instrument for Zudio. The intent that Zudio took in being non-advertising and having a minimal footprint on the internet did not hinder its growth. It was the happy customers who turned brand ambassadors that generated organic awareness and strengthened its credibility as one of the stylish and fashionable yet affordable fashion retailers.

Even though Zudio has established a strong identity, it still has weaknesses in some areas. In the survey responses, while a number of customers reported that they perceived Zudio's product range and quality to be reasonable, the door(s) has been identified for improvements. Increasing product diversity and product quality standards could improve customer satisfaction and strengthen Zudio's competitive edge with its rivals. Furthermore, a considerably high proportion of respondents expressed an interest in online shopping opportunities, indicating that there is a good opportunity for Zudio to enter the e-commerce space. Even though Zudio has avoided digital ways of doing business in order to reduce costs, retailing through an omnichannel strategy could provide Zudio with additional ways to generate revenue and reach younger, tech-savvy consumers.

Zudio's model demonstrates how a retail brand can garner immense success without traditional marketing frameworks. It triggers the emergence of consumer-centric implementation practices, low prices, trending, and a fun place to shop. The proximity of business activities to customer values and behaviours is an importance, which became apparent in the degree of CEM and loyalty potential that could be cultivated in future. Not only did Zudio help to firmly reinforce consumer loyalty, but they also provided a plan for brands wanting sustainable growth in competitive markets. Looking ahead, continued adaptability and innovation is required from Zudio. Increasing product diversity, considering technology integrations, and retaining the low-cost model which Zudio takes pride in, is essential for future relevance and success. Above all, Zudio's journey has demonstrated the importance of strategic focus, whilst challenging previous beliefs of leveraging consumer trust as the nucleus for brand growth. In conclusion, Zudio's rise reflects the significance of identifying and prioritising consumer

interests over traditional behaviours. Zudio has achieved meaningful success without traditional advertising, making retail growth and accessibility an inspiring tale for the global retail industry.

References

- Batra, R., & Keller, K. L. (2016). *Integrating marketing communications: New findings, new lessons, and new ideas*. Journal of Marketing, 80(6), 122–145.
<https://doi.org/10.1509/jm.15.0419>
- Easwaran, R. (2021). *Indian retail industry: Trends and challenges*. International Journal of Management Studies and Research, 9(6), 45–52.
- Kapferer, J.-N. (2012). *The new strategic brand management: Advanced insights and strategic thinking* (5th ed.). Kogan Page.
- Keller, K. L. (2003). *Strategic brand management: Building, measuring, and managing brand equity* (2nd ed.). Prentice Hall.
- Mangold, W. G., & Faulds, D. J. (2009). *Social media: The new hybrid element of the promotion mix*. Business Horizons, 52(4), 357–365.
<https://doi.org/10.1016/j.bushor.2009.03.002>
- Solomon, M. R. (2018). *Consumer behavior: Buying, having, and being* (12th ed.). Pearson Education.
- Verma, H. V. (2020). *Branding in the Indian context: The case of fast fashion retail*. International Journal of Retail & Distribution Management, 48(7), 765–781.
<https://doi.org/10.1108/IJRDM-10-2019-0359>

8

Financial Technologies (FinTech) For Sustainable Investment*Melvin Maclean**Anjali Agarwal*

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Abstract

Financial technologies (FinTech) work as essential instruments for promoting sustainable investments because of their utility in volatile, uncertain, complex ambiguous financial spheres. The paper examines FinTech and sustainability integration by examining the transformative effects of artificial intelligence (AI) and blockchain technology, and digital finance on Environmental Social Governance (ESG) investment models. This analysis examines Indian FinTech developments alongside their transformative effects on financial inclusion while evaluating green finance support for the nation's Viksit Bharat vision (Developed India). This paper uses secondary data and case studies to demonstrate how FinTech innovates with AI-enhanced ESG risk assessment, along with smart contracts operating sustainable supply chains and the tokenisation of green assets. This work investigates the urgent difficulties, which include unclear regulations and data protection concerns, and artificial intelligence shortcomings in making ethical decisions. The study ends with tactical proposals for strengthening sustainable FinTech finance, along with guidance for policy action as well as enhanced public-private cooperative efforts and steps to boost financial capability for green investment promotion. The proper utilisation of FinTech solutions will fast-track India's path to building an open financial framework that meets both inclusivity and sustainability needs.

Keywords - FinTech, Sustainable Investments, ESG (Environmental, Social, and Governance), Blockchain, Green Finance, Viksit Bharat

Dynamic technological development and reforms among regulatory approaches, and the current importance of sustainability, enable significant economic development in the world. The transition has brought us into an era of VUCA (Volatility, Uncertainty, Complexity and Ambiguity) risks which compelling the existing standard financial systems to adjust to modern conditions. The amalgamation of environmental degradation with climate change as part of the income inequality and financial exclusion situation calls for new approaches to creating sustainable development initiatives.

Economic growth has always relied on the financial sector, but common investment patterns have traditionally favoured short-term earnings over social and environmental factors. Financial Technologies (FinTech) itself has transformative effects on the financial market with its implementation of sustainability in the investment decision process. The FinTech field includes among the numerous new innovations: Artificial Intelligence/AI and blockchain technology and the likes, digital lending platforms and robo-advisors and automated ESG (Environmental, Social, and Governance) investment strategies. Recent technological advances enhance the availability, together with clarity and performance of sustainable investment portfolios.

The rapidly growing economy of India is the reason it has Viksit Bharat (Developed India) as its guiding target by 2047 to achieve sustainability in economic growth. Green finance programs and ESG investment criteria as well as policies of digital financial access, are supported by government agencies, including the Reserve Bank of India (RBI) and Securities and Exchange Board of India (SEBI), in supporting India's sustainable economic growth. The march to sustainability-based investments made by the FinTech solutions serves as a central force that builds India's economic sustainability and environmental resilience.

Research Problem & Objective

Research is aimed at analysing changes of the procedures of sustainable investments as induced by FinTech in India. The key objectives include:

- This research examines, in conjunction with blockchain technology, digital finance in promoting ESG investments using AI.
- Characterising the obstacles and opportunities that emerge from the use of FinTech systems to drive sustainable growth.
- The evaluation of governing policies and regulatory frameworks that support FinTech-based green financial solutions

By considering these aspects, the study aims to answer how financial innovations can rather support sustainability while limiting the risk brought about by new technologies.

Research Methodology

This research relies on secondary data research, which combined with reports, academic literature and case studies, studies sustainable investments supported by FinTech. Data collection based on surveying and interviewing of industry experts, policy makers and investors will bring empirical facts that will make the study more practical.

Literature Review

Investment with sustainable finance has developed as a critical research area facilitated by the necessity of responsible financial work and a company's ability to align with the goals of Environmental, Social, and Governance (ESG). The field of sustainable finance, focused on long-term economic growth, minimising environmental and social risks, has been discussed extensively in academic literature. Research has shown that organisations that operate with a robust ESG framework are likely to do better in financial performance in the times to come because they reduce the risk associated with climate change, regulatory compliance and corporate governance (Friede, Busch, & Bassen, 2015). This has seen increased uptake of impact investing; an eventuality where returns from the invested funds are paired with measurable environmental and social benefits (Bugg-Levine & Emerson, 2011).

FinTech has been instrumental in transforming investment landscapes through the introduction of artificial intelligence (AI), blockchain, digital lending platforms and automated ESG investment tools. AI-based solutions have improved the ESG risk evaluation, and investors can run deep analytical techniques on large data sets, Corporate sustainability reports, and real-time financial disclosures. The AI-powered robo-advisors have also made possible the development of sustainable investment portfolios, in that they have been in a position to identify companies that have high ESG compliance (Dorfleitner, Utz, & Zhang, 2021). Research on machine learning models for ESG scoring has emphasised their competence to discover corporate greenwashing and false sustainability assertions, by making ESG investments more transparent (Berg, Kölbel, & Rigobon, 2022).

The Blockchain technology has taken sustainable finance further by providing decentralised, transparent and dignified financial exchange. Studies show that increased liquidity and accessibility of green assets (i.e., green bonds and carbon credits) following the tokenisation of

green assets have benefited investors who seek sustainable finance (Zhang et al., 2021). The application of smart contracts in such a type of supply chain has guaranteed compliance with the environmental regulations and standard ethical practices (Treleven, Brown, & Yang, 2020). Examples of case studies, such as the case of the World Bank issuance of blockchain-based green bonds, have shown that there is potential of blockchain to increase the pool of investors by increasing confidence in investment and improving transparency in sustainable finance (World Bank, 2019).

Other than AI and blockchain, digital lending and crowdfunding platforms have made access to green finance more of a democratization. Participants in peer-to-peer (P2P) lending platforms have opened opportunities for small and medium-scale enterprises (SMEs) to obtain funds for sustainable projects without the patronage of traditional banking institutions (Gomber et al. 2017). The use of crowdfunding platforms like Kickstarter and Indiegogo have made renewable energy startups and social impact companies an available sustainable investment to retail investors. These digital finance models have been most effective in developing economies such as India, where financial inclusion is an important policy priority.

Notwithstanding such developments, a range of challenges remain related to the utilisation of FinTech in investments geared towards sustainability. Large scales in data processing in AI-driven ESG analytics are the main deterrents, especially those related to data security and privacy worries (Zhang et al., 2020). Blockchain, much as it is transparent, is faced with challenges arising from smart contract vulnerabilities and regulatory uncertainties. Regulatory environment related to FinTech-induced sustainable finance is still changing, and respective countries have yet not set uniform regulations on crypto-based ESG investments (Arner, Barberis, and Buckley, 2016).

In addition, there has been an ethical debate accompanying the AI application in financial decision-making. Due to the fact that the AI algorithms are learnt from historical data, they are prone to miners of carrying over biases that may result in discriminatory ESG ratings and investment decisions (Hurlburt & Bojanova, 2020). The inscrutability of AI-based investment strategies has led regulators to seek enhanced control of automated financial judgments.

The way from a policy point of view, the various international and national regulatory frameworks have started to emerge to enhance FinTech-driven sustainable finance. Emphasis has been put on clarity in sustainability reporting and ESG investment transparency by the European Union's Sustainable Finance Disclosure Regulation (SFDR) and the Task Force on Climate-Related Financial Disclosures (TCFD) (EU Commission, 2021). There are also initiatives in the form of SEBI's ESG investment guidelines and RBI's green finance initiatives

that India introduces in order to incentivise financial institutions to institutionalise sustainability in their investment plans. Such policies are highly critical in promoting responsible FinTech (for green finance) adoption.

Although the potential of FinTech in sustainable investments has been well-written about in existing literature, there still remain research gaps concerning the long-run impacts of the AI-driven ESG investments, the implications of the use of blockchain for sustainable finance, and country-cross comparisons of FinTech policies. Also, longitudinal studies will be necessary to measure the evolution of sustainability initiatives driven by FinTech over a time period. Future research should focus on the creation of more standardised global metrics for ESG metrics and the feasibility of scalability of blockchain-based solutions to matters of sustainability, and social impact on digital lending models in sustainable finance.

Understanding the Fintech Landscape in India

Major changes took place in India's financial system through the rapid expansion of Financial Technologies (FinTech). The FinTech revolutionised banking as well as payments and lending, and investments over the past ten years, which brought advanced finances and self-styled digital money transfers. The combination of digital payment integration with blockchain technology and AI-driven financial services, along with alternative lending models, facilitates financial services that are more accessible and more efficient and more transparent.

The nationwide Digital India campaign, along with Prime Minister Jan Dhan Yojana (PMJDY) and Unified Payments Interface (UPI) programs and regulatory improvements from RBI & SEBI, has built a suitable environment for FinTech development. FinTech today fulfils two complementary goals because it turns over traditional finance systems via green financial solutions, ESG management strategies and impact-based financial products.

British Universities become keen to better understand the true level of impact of FinTech in India by analysing together with some new breakthroughs, such as digital loans and blockchain-assisted visibility and AI-based green investment solutions, financial inclusion efforts. The section introduces a review of regulatory aspects concerning FinTech adoption and its SDG advancement role in India's sustainable development space. FinTech capabilities are based upon the understanding of the existing FinTech climate, as it will reflect how the Sinvestment made in sustainability will fit into the plan of India becoming Viksit Bharat 2047.

Evolution of Fintech And Its Impact on Financial Inclusion

The Indian financial technology (FinTech) industry has grown as an important economic accelerator that stimulates financial inclusion, digital empowerment, and economic development over the last two decades. The introduction of FinTech of mobile banking, digital payment systems and robo-advisors, to name a few, and in tandem with technologies of blockchain has dramatically changed the established financial business in the FinTech sector. This change has led to the appearance of complex, inexpensive, and available financial substitutes. The demonetization, which was undertaken in 2016, coupled with the Digital India campaign, greatly accelerated the uptake of digital financial services. Such a trend not only promoted cashless transactions rather than cash payment methods but also caused an increase in financial literacy on the part of the population in both rural and urban parts of India.

The wide-scale use of FinTech as a primary positive effect on India because it will enable all client segments to access banking services. Traditional financial services have remained accessible only in urban cities in the prehistoric era, thus cutting off a major portion of rural unbanked population from banking services. Through simple banking and credit services, FinTech solutions, such as Paytm and PhonePe and Google Pay and digital lending platforms, and microfinance technologies have resolved this challenge. Through the rise of the Unified Payments Interface (UPI), digital payment infrastructure has grown stronger in enabling people and small businesses to transact with each other in an easy peer-to-peer mode.

The direct benefit transfer system, powered by innovations in FinTech, brought operations of PMJDY beyond its borders to channel funds through bank accounts and deploy insurance solutions and microcredit programs. Digital-only financial institutions in addition to neo-banks, have introduced special financial products to attract people to enter financial networks, avoiding traditional banking techniques.

Major FinTech Solutions Enabling Sustainable Finance

FinTech serves as an enabler to develop ESG-oriented financial solutions due to its sustainability significance and the emergence of green finance. New modern innovative technologies change the way investments and lending processes, and transaction systems are involved in sustainable economic growth.

1. Digital Payments and Financial Accessibility

Rapid adoption of UPI, mobile wallets, and digital banking platforms has not only made cashless transactions possible but has also created discipline and a measurable form of financial behaviours. Such technologies reduce ecological impact with regard to paper transactions while increasing financial transparency and accountability.

2. Blockchain for Green Investments and Transparency

The Blockchain technology is becoming more important in the ESG financing, particularly in promoting transparency in supply chains, where investors are able to participate in a supply chain, green assets tokenisation, and the carbon credit market. Smart contracts based on the technology of blockchain enable automatic, verifiable, and unalterable financial transactions that ensure the use of the green funds is consistent with their destination. Organisations are enacting the use of blockchain-based ESG score systems to improve their sustainability reports.

3. Robo-Advisors and AI-Driven ESG Investments

There is a big transformation in sustainable investing as AI-driven robo advisers are providing customised investment strategies based on Environmental, Social and Governance (ESG) criteria. These platforms are using artificial intelligence to analyse the market trends, corporate compliance with ESG standards and preferences of the investors to make recommendations on investment portfolios which are responsible. AI is strengthening the reliability and attractiveness of ESG investments with the adoption of machine learning models used in estimating climate risks and sustainability results.

4. Digital Lending for Green Startups and MSMEs

Traditional financial institutions often place rigid requirements that prevent green startups, renewable energy firms and small businesses from financing their operations. Financial technology-enabled peer-to-peer (P2P) lending platforms and digital microfinance options have become alternative means of capital for sustainable businesses outside the traditional constraints of collateral requirements. Further, these platforms use artificial intelligence to review other credit scores, hence widening the lending opportunities for the previously marginalised groups.

5. Crowdfunding and Impact Investing Platforms

The rise of such platforms based on financial technology has made it easier for individuals and organisations to become involved in sustainable projects with lower capital costs. These have

innovatively opened up new avenues for sustainable investments through such platforms as Kickstarter and Indiegogo, and even among the Indian crowdfunding platforms *Milaap* and *Ketto*, which have helped sustain renewable projects in energy and clean technology innovations, as well as social impact enterprises.

Regulatory Framework and Government Initiatives

India's regulatory framework has responded dynamically to the rapid pace of growth of FinTech, while focusing on the stability of finance, security and fulfilment of sustainability goals. The Reserve Bank of India (RBI), the Securities and Exchange Board of India (SEBI), and the Ministry of Finance developed several policies for promoting the responsible growth of FinTech.

1. RBI's Green Finance Initiatives

The Reserve Bank of India (RBI), through the Sustainable Finance Group (SFG) has really played a key role in creating a policy framework that has encouraged green banking and sustainable finance initiatives. The RBI's report of 2022, on Climate Risk and Sustainable Finance, noted the importance of climate risk assessment being included in the lending/investment strategies of the financial institutions.

2. SEBI's ESG Investment Guidelines

To enhance the transparency involved in Ecosystem, Society and Regulatory (ESG) considerations, the Securities and Exchange Board of India (SEBI) created mandatory disclosure frameworks for the largest 1000 listed companies in the country. These directives are meant to encourage corporate responsibility of investing, encourage audit of corporate sustainability, and ensure that ESG information is accessible to investors before making investment decisions.

3. Digital India Initiative and FinTech Adoption

The Government of India's Digital India initiative has been a catalyst to develop advancements in FinTech and in increase the financial inclusion and the development of the digital infrastructures. Through supporting cashless transactions, digital banking and AI-based financial solutions, this initiative has created a solid foundation for integrating FinTech in the context of sustainable finance systems.

4. India's Push for Green Bonds and Renewable Energy Investments

India has managed to position itself as a frontrunner in green bonds issuance, providing investors with financial instruments which are climate change resistant. The government's

regulatory promises to promote investments in renewables via tax incentives, policy frameworks, and technology-driven green financing platforms have spurred the country toward a low-carbon economy.

The Role of Fintech in Sustainable Investments

Sustainability goals for economic development are driving a major realignment of the global financial landscape as economies try to adjust their investment position based on sustainability goals for economic development. Financial Technologies (FinTech) are increasingly becoming powerful tools that aid in balancing financial expansion with good environmental stewardship. Such innovations as Artificial Intelligence (AI), blockchain technology, digital lending, and a platform of impact investing are changing investment management and increasing transparency, accessibility, as well as environmental responsibility.

FinTech acts as an important channel to enable Environmental, Social and Governance (ESG) investments in a sustainable finance framework. It provides clarity for the green financing as well as increases financial options for the small enterprises and startups that operate in the sustainability-based field. With the use of a lot of data analytics, Decentralised finance (DeFi) and the automated investment system, FinTech promotes investment practices that follow the international sustainability agenda.

This chapter reviews three key dimensions of FinTech's presence in sustainable investment. ESG investments boosted by AI, blockchain-based transparency, and digital lending, and crowdfunding centred on green finance.

Green & ESG Investments

1. AI-Driven ESG Risk Assessment and Scoring Models

The infusion of Artificial Intelligence (AI) in Environmental, Social, and Governance (ESG) investing is revolutionising the evaluation and approach to analysing sustainability risks. Previously, the ESG judging was based on corporate disclosures, external ESG ratings, and various interpretations of sustainability reports. However, such methods often triggered mixed assessments and a tendency to greenwash, which means firms are pretending to invest large amounts of money in addressing global warming issues.

AI-based ESG scoring systems have transformed this framework in the following ways:

- Handling large datasets in real-time, such as regulatory papers, corporate sustainability reports, and satellite pictures to measure the real environmental performance of a company.
- Using Natural Language Processing (NLP) to extract insights on greenwashing and sustainability threats from articles published in news, social media activity and financial documents.
- Based on the application of machine learning to recognise climate-related risks and failures in governance prior to achieving critical financial impact.

Evaluating the relevance of AI-enabled robo-advisors in ESG investing, too, is also increasing in importance. These platforms:

- Develop customised ESG portfolios based on reviewing investors' preferences, their risk appetite and their sustainability goals.
- Persistent monitoring of ESG performance of investments and portfolio adjustments based on lifting sustainability dynamics.
- Provide predictive analytics in order to be able to calculate the potential future ESG implications of various potential investments.

Example: ESG risk services offered on platforms such as MSCI ESG ratings, Refinitiv, and Arabesque S-Ray offer AI-enabled ESG risk assessment that helps the investor make accompanied decisions on the basis of data.

2. FinTech Platforms Enabling Retail and Institutional Sustainable Investments

FinTech has made sustainable investment easier to practice for both institutional and retail investors. Traditionally, the high level of capital required (thus making involvement expensive) and the need for extensive research in sustainable investments limited the level of participation to institutional investors. However, smaller investors are now able to invest in ESG through the platforms powered by FinTech in the following manner:

- AI investment platforms which are automated and have ESG portfolios, e.g Betterment & Wealth front.
- Integer applications like Acorns and Ellevest that allows the users to contribute small amounts to funds that are oriented to sustainability.
- Sustainable exchange-traded funds (ETFs) and index funds which utilise the power of data analytics to find companies that adhere strongly to ESG.

Meanwhile, institutional investors benefit from immediate ESG analytics that enhance strategies based on outcomes of sustainability. Other ESG data sources, such as IoT-supported

environmental observation and blockchain carbon credits tracking help to optimize investment options.

Blockchain & Transparency in Sustainable Finance

1. Smart Contracts for Sustainable Supply Chains

Blockchain technology plays a great role in transparency and accountability in finance. A major application of blockchain in sustainability is its capacity to facilitate smart contracts—automated digital agreements that guarantee compliance with environmental, social, and governance (ESG) criteria in financial deals and supply chains.

Smart contracts promote sustainability by:

- Automating the reporting of ESG compliance, so businesses fulfil their sustainability obligations before being paid or funded.
- Reducing fraud in green financing through a verification that money allocated for renewable energy initiatives or carbon offsetting programs is expended appropriately.
- Enhancing traceability in the supply chains, in industries such as agriculture, fashion, and manufacturing, where the ethical conduct of labour practices and environmental rules needs to be met.

Example: IBM's blockchain-driven supply chain solutions help organisations track carbon emissions and also ensure transparency in fair trade, thus improving corporate accountability concerning ESG standards.

2. Tokenisation of Green Assets and Carbon Credits

Blockchain technology enables the tokenisation of financially sustainable resources which are environmentally friendly, such as green bonds, renewable energy credits and carbon offsets. Investors can purchase fractional integration on unsustainable initiatives, made possible through tokenisation, thereby improving liquidity and access.

Advantages of blockchain-enabled tokenisation:

- Higher liquidity: Investors are in a position to trade digital tokens which denote carbon credits and investments in renewable energy.
- Lower transaction costs, which are facilitated by the lack of intermediaries in decentralised platforms, are made more seamless in financing green projects.

- Bigger transparency: Public blockchain ledgers offer the unaltered records of the transactions contributing to sustainability.

Example: The World Bank had issued green bonds using blockchain technology, exemplifying how decentralised finance is improving efficiency and transparency for climate financing.

Digital Lending & Crowdfunding for Sustainability

1. Peer-to-Peer (P2P) Lending for Green Startups

These traditional banks usually have harsh terms of borrowing, which can prevent green startups from accessing finance. As a solution to the problem, FinTech-based P2P lending platforms are associated with linking investors directly to entrepreneurs in sustainability-motivated sectors.

Key Advantages of P2P Lending in Sustainable Finance:

- Alternative credit assessments risk assessment powered by artificial intelligence – incorporates non-financial information, including energy consumption trends, mobile payment records, and online transaction outlays in order to determine credit worthiness.
- Lowered interest rates – With zero banking fees and external intermediaries in direct lending between investors and borrowers, there are lower interest rates.
- More financial accessibility – Small businesses and social businesses dedicated to renewable energy, water conservation and sustainable farming are more easily able to secure loans.

Example: Website such as Raind ve Kiva provide microcredit to rural entrepreneurs who focus on Sustainable Agriculture and Clean Energy initiatives.

2. Crowdfunding and Impact Investing Platforms

Crowdfunding sites have become a useful means to crowdfund sustainable projects. Such platforms allow one to financially contribute to initiatives linked with the use of renewable energy, programs that promote climate resilience, as well as community conservation projects.

Types of Sustainable Crowdfunding:

- Reward-based crowdfunding: People fund eco-friendly projects in consideration for incentives such as early access to green products.
- Equity crowdfunding: Investors purchase shares for startups which focus on sustainability.
- Debt crowdfunding: Companies get funded for environmentally friendly projects by borrowing from private investors.

Example:

- Indian crowdfunding sites, such as *Milaap* and *Ketto*, have assisted businesses in the solar initiatives and waste recycling firms financially.

Challenges and Risks in Fintech for Sustainable Investments

Financial Technologies (FinTech) have given birth to creative solutions with the specific objective of supporting sustainable investments. However, they also present a lot of challenges and risks that need to be addressed. Concerns such as data security, regulatory vagueness, scalability, and ethical questions act as barriers to the wide adoption of FinTech-enabled sustainable finance. This part will address these challenges extensively, discussing their impact on investors, financial institutions, and regulators.

Data Security and Privacy Concerns

1. Risks Associated with Digital Transactions and Financial Data

- FinTech platforms handle large volumes of sensitive financial data such as investor profiles, ESG ratings, and carbon credits transactions. With more and more relying on cloud computing, artificial intelligence and blockchain technology, these platforms become vulnerable to cybersecurity threats like:
 - Data breaches in which hackers acquire personal financial and investment data.
 - Identity theft against investors whose investments are in digital lending and crowdfunding initiatives focusing on ESG principles.
 - Access to AI based robo advisors with wrong transactions.
- Regrettably, while its security features are recognised, blockchain technology has not eliminated all risk. Fraudulent ESG investments via exploitable vulnerabilities in smart contracts mean that ownership of green assets is lost.

2. Lack of Standardised Cybersecurity Measures

- While the dominance of digital formats in financial services continues to grow, numerous FinTech companies do not have reliable security measures to protect against digital cybersecurity threats that would secure investor information.
- Weak encryption usage and not enough authentication standards expose digital transactions and blockchain activities to increased cyber threats.

- International ESG investments are greatly at risk with no universal cybersecurity standards for FinTech sustainability platforms.

Regulatory Compliance and Legal Uncertainties

1. Challenges in Regulating AI-Driven ESG Analytics

- Currently, financial regulatory agencies do not fully monitor robo-advisors which utilise AI to analyse and score the ESG factors.
- Significant risks include:
 - There are risks for misleading ESG ratings with AI due to a lack of visibility on the algorithms' input into AI, which may help select certain firms.
 - Trivialising the regulatory standards for recommendations provided by AI in investment decisions, leading to automated selections where accountability is vague.
 - The possibility that AI-enhanced sustainability decisions are fallacious because inaccurate information sets may over- or understate actual ESG performance.

2. Uncertainty in Blockchain and Cryptocurrency-Based Green Investments

- Many financial laws currently do not accept tokenised ESG assets that rely on blockchain technology, including green bonds and carbon credits.
- The bulk of the existing financial regulations do not recognise tokenised ESG assets under blockchain technology, such as green bonds and carbon credits.
- Challenges include:
 - There are no known frameworks which regulate ownership rights of tokenised ESG assets during massive price falls.
 - The crypto-based green investments are not under clear or established regulatory guidelines at present.

3. Absence of Standardised Global ESG Regulations

- In contrast to conventional financial markets, the realm of sustainable investing facilitated by FinTech lacks a standardised regulatory framework. Various nations implement differing norms for ESG disclosures, which complicates the ability to:

- Evaluate the genuineness of claims related to sustainable investments.
- Verify that FinTech platforms adhere to global ESG standards.
- Enable cross-border investments in green bonds, carbon credits, and impact funds.
- The regulatory discrepancies in ESG investing encompass:
 - The problem of greenwashing may arise when firms exaggerate sustainable achievement due to a lack of regulations and disclosure requirements.
 - Various approaches to ESG scoring can generate uncertainty in investors' understanding of a company's actual environment and social performance.

Scalability and Accessibility of Sustainable Investment Platforms

1. High Entry Barriers for Small Investors

- While Fintech tries to democratize investment in sustainable opportunities across the maps, several barriers discourage small investors from full involvement. Such as:
 - Very strict fees are charged on blockchain-based platforms that focus on ESG initiatives.
 - Building investment in green bonds and impact funds requires a particular amount of funds to get in.
 - AA-driven sustainable investment platforms have limited access primarily to developed economies, with developing nations lacking the infrastructure.
- Although institutional investors have access to the sustainable FinTech platforms, conventional investors have trouble remaining involved in green finance endeavours.

2. Technological Infrastructure Challenges in Emerging Markets

- One of the major challenges faced by developing countries is obtaining the required infrastructure to help in the implementation of FinTech solutions towards sustainability. Key challenges include:
 - Limited access to high-speed internet and difficulties in reading digital information make it hard for people to put to use AI-focused ESG initiatives.
 - Lack of support for digital green finance by governments of emerging markets results in major delays in the implementation of financial policies.

- The amount of blockchain and digital lending for sustainability implementation is limited, thus restraining green startups from the financial resources they need.

Ethical Concerns in AI-Driven Financial Decision-Making

1. AI Bias in ESG Investments

- AI-based ESG scoring models contain biases from their training datasets which produce the following effects:
 - Inclusion of some companies in ESG indices calls for incomplete data assessment for qualification.
 - Small but meaningful green businesses are not captured by AI-driven risk assessments.
 - Digital lenders are vulnerable to nonsensical declines to certain sustainable businesses due to incorrect risk assessment criteria stipulated by AI.

2. Lack of Transparency in AI-Driven Robo-Advisors

- A number of investors lack a comprehensive understanding of how AI-driven robo-advisors distribute ESG funds, resulting in:
 - Horror about AI-related investment management because decisions are made without human oversight.
 - Challenges emerge in the process of verifying ESG data obtained through AI, which complicates the accurate analysis of the results of sustainability.
 - The possibility of AI-influenced market trends being skewed, which might prefer certain ESG funds over others.

3. Social and Environmental Impact of AI in Finance

- There is a generation of environmental emissions by the use of AI and blockchain in the FinTech systems, which opposes the sustainability milestones.
- Key concerns include:
 - Trading of carbon credits and blockchain, in addition to ESG asset trading, has a highly consumptive and high-energy consumption level.
 - The execution of AI financial algorithms in large computing systems produces significant compounds at data centres.

- To ensure that the green investments do not incidentally cause adverse environmental effects, the FinTech firms should effectively promote sustainable technology.

Future Prospects and Recommendations for *Viksit Bharat*

India's vision for Viksit Bharat 2047 proposes strategies and methodologies to build a resilient economy utilising advanced technology in order to guarantee universal financial access and a deep sense of environmental sustainability. The implementation of Financial Technologies (FinTech) solutions will place a significant focus on helping India realise its economic vision to achieve its country's Environmental, Social and Governance (ESG) needs.

Realisation of this vision needs policy shifts accompanied by the improvement of financial intelligence, strengthening of the public-private interface, and the integration of advanced technology into the sustainable finance systems. This section examines means of leveraging FinTech investments to propel sustainability in India with practical approaches that can be taken to promote the development of sustainably driven technology in India.

Future Prospects of FinTech-Driven Sustainable Finance in India

1. Growing the use of AI and Big Data in ESG sustainability investing

- As ESG metrics get integrated with AI, they will become complex in nature and facilitate companies to be able to evaluate science-based sustainability performance at a faster and more accurate rate.
- Machine learning algorithms can be used to improve predictive risk modelling so that investors can stop early and identify climate-related financial risks.
- Enhanced with Big Data analytics, investors could have richer data on the area of carbon emissions, resource use, and labour standards, which will translate to transparent investment decisions.

2. Fulfilment of the deployment of blockchain to improve green financial services

- Blockchain-enabled smart contracts will be a common tool for facilitating supply chain finance, trading of carbon credits and establishing green bond offers.
- Retail investors can have access to great enterprises for clean energy by tokenising green energy assets.

- Decentralised financial (DeFi) platforms will facilitate opportunities for green lending better and access to microfinance services.

3. Improving Digital Payments to Increase Financial Inclusion

- Fintech digital payment solution will be a game changer for facilitating access to financial services and in resourced areas and poor populations.
- UPI's integration of transactions linked to ESG allows consumers to shop sustainably based on their choice to engage responsible companies.
- The introduction of AI will strengthen security as well as consumer confidence in digital financing systems.

4. Expansion of Sustainable Crowdfunding and Impact investing

- Such green crowdfunding platforms should become bigger in size so that members could make investments in renewable power, infrastructures that are climate-resilient infrastructure, and social enterprises.
- Impact Investments foster...funds to...businesses in the area of clean technology, circular economy and running conservation projects for the sake of biodiversity.
- Sustainable financing procedures aim at facilitating institutions with a leading sustainability rationale.

5. Government-Led FinTech Adoption for Sustainable Development

- Policy guidelines intend to encourage firms like banks and financial institutions to be encouraged to bring their operations in line with sustainability-linked loans and investments that support impact.
- Funding of sustainable infrastructure using FinTech innovations will be primarily through PPPs between public and private entities.
- Sandbox platforms, which serve as risk-testing grounds, enable the new innovations of green financial products by FinTech firms to be checked before the mass-scale distribution of the products.

Key Recommendations for Leveraging FinTech for *Viksit Bharat*

1. Policy Interventions to Support FinTech-Driven Sustainable Finance

- For publicly listed companies, the ESG information has to be provided through the blockchain-based transparent reporting systems, and mandated to be disclosed according to prescription.

- We should encourage FinTech ventures in sustainable finance by blending tax incentives with grant programs.
- The National Sustainable Finance Roadmap needs to have clear goals to demonstrate what role FinTech serves in supporting climate finance and green investments.
- Standardised ESG evaluation procedures for FinTech platforms, accompanied with ethical AI Governance, should be proposed by the RBI and SEBI to improve their financial regulations on FinTech platforms.

2. Enhancing Financial Literacy for Green Investments

- The institution will introduce digital learning platforms for teaching ESG principles, sustainable banking management and ethical loan practices.
- Sustainability finance education should be featured in university programs and vocational training.
- Community-based programmes should make it a point to engage small investors and small-scale entrepreneurs to learn about the advantages of the sustainable digital financing systems.

3. Strengthening Public-Private Partnerships for ESG Financing

- Support of collaborations between banks, FinTech enterprises and government agencies to develop new innovative financing opportunities for sustainability.
- Collaboration between the public sector and climate-friendly projects should establish financing structures which protect private sector investment.
- India is in a position to attract investments from multinational companies (MNCs) to finance green FinTech startups.

4. Leveraging AI and Big Data for Real-Time Sustainability Tracking

- Companies need to increase their usage of AI-driven climate risk analytics systems in order to improve the assessment of the financial implications of extreme weather and natural disasters.
- With satellite data and IoT sensors, as well as fintech solutions, firms are able to carry out continuous, immediate ESG compliance cross-checks of firms.
- FinTech companies should be encouraged to use AI predictive analytics in predicting and managing risks in their green investment projects.

5. Promoting Regulatory Frameworks for Ethical AI in FinTech

- Financial institutions should establish rules that allow users to understand how AI-based scoring affects ESG evaluations and automated investment systems.
- Finance industry decision systems utilising AI must operate without prejudice and provide all capital seekers with equal and fair access to funding opportunities.

Conclusion

By merging Financial Technologies (FinTech) into sustainable investments, the Indian financial service industry is revamped such that economic growth is in tandem with the ESG philosophy. Within the VUCA context, digital financial technologies use AI to address ESG factors and use Blockchain to increase transparency in order for digital lending platforms to finance green start-ups and experiment with ethical investment practices. These new-age technologies strengthen financial inclusion as well as the development strategies for sustainability in line with the aspirations of Viksit Bharat 2047.

In the research paper, the most important facets of how FinTech facilitates sustainable investments were analysed:

- The study showed a very great improvement in the financial reach of India's FinTech sector, with UPI, mobile banking, and digital lending platforms playing a vital role here. India's implementation of policies like PMJDY, SEBI's ESG guidelines and RBI's Green Finance activities has highly encouraged the existence of co-existence of FinTech and sustainability goals.
- The paper illustrated that the use of AI-enabled ESG scoring, blockchain-supported green finance measures, and crowdfunding operate as aspects that promote the adoption of data-driven, transparent and transformative sustainable investments. Such innovations add to the annihilation of greenwashing dangers, promote ongoing monitoring of environmental and social indicators, and further increase access to financial products that align with responsible investments.
- By looking at challenges and risks of sustainable investments from the FinTech lens, a number of major hurdles were found, such as cybersecurity weaknesses, ambiguity about regulations, AI biases, and addressing issues related to automated ethical decision-making. There is a need for strong cybersecurity, concordant ESG regulation and a pure ethical soul for AI systems.

- Aside from that, the agenda for Viksit Bharat suggested various strategic steps for the use of FinTech in sustainable finance, including changing policy, improving the education of finance, increasing cooperation between stakeholders and the use of AI to track climate risks.

Key Takeaways and Implications for *Viksit Bharat 2047*

1. FinTech is a major driver of sustainable finance through innovations in artificial intelligence, blockchain, and digital lending, promoting ESG investment, financial transparency, and access.
2. The most important issue to be addressed in securing progress in sustainable finance is regulatory uncertainties, cybersecurity threats and AI biases. Enhancing legal standards and ethical follow-throughs in AI applications will be primary elements in ensuring the persistence of FinTech success.
3. The role of Public-private partnerships in accelerating the integration of sustainable finance into public markets will be a key one. Inter-relationships between government departments, the FinTech enterprises and the financial institutions will be critical in facilitating innovation, driving financing for climate change and social impact.
4. Increasing knowledge about environmental, social, and governance issues should become a priority. It is possible to increase consumers' awareness about eco-conscious finances among such parties as investors, businesses, and policymakers, which will motivate them to use more sustainable methods of financing.
5. Regulatory developments will determine the path of sustainable FinTech in the future years. With the frameworks or ESG in India, the Reserve Bank of India's green finance strategy and the rules by the Securities and Exchange Board of India on sustainable investments, a robust and policy-driven environment can be created for FinTech-based sustainable projects.

FinTech provides opportunities for guiding India towards a more robust, fair, and environment-friendly economic regime. Integrating AI for assessing ESG risks, installing blockchain for open finance, and facilitating digital payments to promote impact investing are the major steps that India must take to be a firm standout in sustainable finance. To capitalise on this potential, it is important to develop good plans on regulation, convergence of technology, and human resource improvement. With India's journey to *Viksit Bharat 2047*, the combination of FinTech and sustainability will be one of the main pillars for the future financial stability, Nature conservation, and sustainable economic growth.

References

Books and Research Papers

- Arner, D. W., Barberis, J., & Buckley, R. P. (2016). The evolution of FinTech: A new post-crisis paradigm? *Georgetown Journal of International Law*, 47(4), 1271-1319.
- Bugg-Levine, A., & Emerson, J. (2011). Impact investing: Transforming how we make money while making a difference. Jossey-Bass.
- Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment*, 5(4), 210-233.

Government Reports and Policy Documents

- Reserve Bank of India (RBI). (2022). Report on Climate Risk and Sustainable Finance. Retrieved from www.rbi.org.in
- Securities and Exchange Board of India (SEBI). (2023). ESG Reporting Guidelines for Listed Companies. Retrieved from www.sebi.gov.in
- Government of India. (2021). Digital India Programme: Advancing Financial Inclusion Through FinTech. Ministry of Electronics and Information Technology.

Academic Journals and Articles

- Berg, F., Kölbel, J. F., & Rigobon, R. (2022). Aggregate confusion: The divergence of ESG ratings. *The Review of Financial Studies*, 35(3), 1347-1385.
- Dorfleitner, G., Utz, S., & Zhang, R. (2021). The pricing of green bonds: Evidence from the primary and secondary market. *Journal of Financial Economics*, 142(1), 202-231.
- Jiang, W., Wu, Q., & Wang, R. (2020). AI-driven ESG risk assessments: The future of sustainable investing. *Harvard Business Review*, 98(4), 78-90.

Industry Reports and White Papers

- IBM. (2022). Blockchain for Sustainable Supply Chains: Improving ESG Transparency. IBM Research. Retrieved from www.ibm.com
- World Economic Forum. (2021). Harnessing FinTech for a Sustainable Future. Retrieved from www.weforum.org
- United Nations Environment Programme (UNEP). (2020). Green Finance and FinTech Innovation for Sustainable Development. Retrieved from www.unep.org

Online Sources and News Articles

- Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. Retrieved from <https://bitcoin.org/bitcoin.pdf>
- The World Bank. (2019). Blockchain-Based Green Bonds: A New Model for Sustainable Investing. Retrieved from www.worldbank.org
- Financial Times. (2023). The Role of AI in ESG Investing. Retrieved from www.ft.com

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**A Review on Sustainability through Natural Eco-Friendly Finishes
Extracted From Spinach on Cellulosic Textiles and Integration of AI to
Reduce the Impact on the VUCA World**

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Abstract

Previous research has shown that Natural Flame Retardant Finishes can be acquired through the application of Spinach Extract on Cotton fabric. The additional research based on it proved the presence of Antimicrobial Activity as well. Flame retardant finishes not only require a high amount of chemicals but are also expensive and are non-biodegradable. Similar is the need for antimicrobial finishes initially used for the medical sector have gained higher demand in daily apparel after the pandemic. These finishes contain phosphorus, halogenated-based compounds, silver, polyhexamethylene biguanide, quaternary ammonium compounds and triclosan, which are hazardous to nature. Application of synthetic finishes on natural materials such as cotton makes it non-biodegradable, adding a concern to the VUCA World. Thus, this research paper explores Spinach Extract as a sustainable alternative for textile finishes and the key focus is laid on the Integration of AI, as it is the need of the hour. Natural Finishes possess a common limitation of non-durability and require timely reapplication. With the help of AI, detection and regulation of the finishes can be tracked and assessment of the finished textile can be done with accuracy. Research on AI has proved the functionality of Flame Retardancy and Antimicrobial activity on Textiles. This paper explores the use of AI in the textile sector and its integration to enhance the limitations of natural, eco-friendly to more Sustainable and Durable finishes.

Keywords: Sustainability, Spinach Extract, AI, Antimicrobial, Flame Retardancy.

Understanding VUCA

VUCA is an acronym representing four key challenges—volatility, uncertainty, complexity, and ambiguity—that make it difficult to analyze, respond to, or plan for a situation, thus prompting for development of strategies, effective leadership and decision making from small to large entities. **Volatility** refers to the tendency of a situation to undergo frequent, rapid, and significant changes. For instance, in a volatile market, commodity prices may fluctuate drastically within a short period, and trends can reverse suddenly. **Uncertainty** arises when future events and their outcomes are unpredictable. There is a lack of clear cause-and-effect relationships, making it difficult to rely on past experiences for guidance. In an uncertain market, for example, price movements are unpredictable, and the extent of change remains unknown. **Complexity** involves multiple interrelated factors that are difficult to fully comprehend. The connections between elements may be intricate, and a change in one area can trigger unintended consequences elsewhere. In a complex market, for example, fluctuations in gas prices can impact the cost of unrelated goods due to interconnected supply chains. **Ambiguity** occurs when a situation lacks clarity, making it difficult to interpret information correctly. Misinterpretations and misunderstandings are common, and the goal or expected outcome may not be evident. In an ambiguous market, for instance, hidden influences and incomplete information can affect pricing and decision-making. (Wright,2020)

Volatility, Uncertainty, Complexity, and Ambiguity impact depends on various internal and external factors. A prominent example is the global COVID-19 health crisis, which has significantly impacted numerous occupations, creating a dual effect. For some businesses, VUCA presents an opportunity to reassess their value and refine their strategies for long-term sustainability. It also serves as a platform for business leaders to evaluate their capabilities and enhance their leadership skills. Uncertain and unpredictable environments often generate new opportunities, allowing managers to restructure and rethink business operations. (Raja,2021)

Sustainability in Textiles

The global textile industry, a significant driver of many nations' Gross Domestic Product (GDP), is increasingly under scrutiny for its environmental and social impacts. As the largest manufacturing sector in terms of production volume and workforce, it is also among the most resource-intensive and polluting industries. Rising consumer awareness and a growing demand

for sustainable practices are pushing efforts to improve sustainability in both textile production and consumption. Environmental sustainability is of great significance for the Textiles and Fashion Industry. The manufacturing of textile products consumes significant resources and has the potential to create serious environmental issues. This industry ranks highest in water pollution, greenhouse gas emissions and waste generation. With the increasing demand and production, fast fashion has a toll on the landfills. The intricate problem in this industry is not one but every stage contributes to environmental issues because of the product. Beginning with the cultivation of cotton, the water and soil pollution is higher as developing countries do not have the means to implement environmentally safe practices, and similarly, the synthetic and regenerated fibre production requires high use of chemicals. Gradually, the spinning of yarn, construction fabric, Dyeing, finishing, printing, the apparel production consecutively builds on the impact of chemicals. The dyeing and finishing, also known as the wet processes, as tons of fresh water. Even after the extensive labour and resources, the life cycle of the garment contributes very less contributing to the landfills, and the decomposition of the fabrics is equivalent to that of plastics. Even if natural material is used, the synthetic component delays the disintegration process, or the chemicals used leach to the environment. Therefore, to reduce the intensity of damage, each stage must be scrutinised thoroughly for sustainable practices to be adopted.

Cellulosic Textiles and the Need for Functionality Finishes

Cotton is a natural material obtained from plants. It is one of the most preferred and versatile fibres, and the inherent qualities of absorbency, softness, breathability, strength, easy handling, durability, machine washability, drapability, colour retention, wrinkle resistance make cotton fibre in highest demand till date. Even though many other fibres are available in natural, synthetic, and regenerated categories, cotton is often blended with higher percentages as it is the most comfortable fibre in apparel. Almost 135 types of cotton varieties are present, which marks the versatility of the fibre; right from the strongest material for ropes, jeans, and duck fabric to the lightest feather-like fabrics such as voile and muslins. Therefore, it is not surprising that cotton is regarded as the 'King of textiles. However, there are some major drawbacks of cotton and all natural fibres, such as being susceptible to microbial activity, shrinking, easily susceptible to catching fire and wear & tear over time.

Cotton is also known as a cellulosic textile as it is composed of cellulose, proteins, pectins, and other inorganic substances. Due to the diverse use of cotton, where it may be subjected to

moisture for a long period of time, leading to the growth of microbes, causing damage to the fabric by deterioration of fibres, staining, yellowing, discolouration, and odor. Since it is widely used in apparels, upholstery, and industries, another issue is of fire hazard. The primary reason for fire accidents is because of cooking i.e. in the kitchens. (Firechief Global, 2021) The spread of fire is faster due to fabrics and therefore the need for flame retardant finishes. This paper reviews these finishes and how a natural finish obtained from Spinach extract has dual functionalities. Also, one aspect of the textile industrial process - the finishes on the garment is discussed further. Finishes are applied after the dyeing process to provide various functions and aesthetic properties to the textile. Natural eco-friendly finish obtained by Spinach gave the functionality of flame retardancy and antimicrobial activity. (Thanawala, 2021). Furthermore, to build upon the limitations of the natural materials with the current advancements in the technological field - Artificial Intelligence AI; previous researches and new possibilities are discussed in this paper.

Methodology

The methodology for reviewing the paper consisted of the collection of data from online resources and a detailed review and analysis of the data. The research papers were accessed through valid sources such as Research Scholar, ResearchGate, Emerald Insights, the Journal of Textiles. The flow of collection of data collection began with the focus on the finishes to the sustainability of the industry.

Review of Literature

Finishes in Textiles

Every fabric goes through a lot of processes for a garment to be made. Right from yarn to fabric, it requires a tedious physical, mechanical, chemical, and laundering process. Textile Finishing is the process of improving the appearance, feel and performance of a fabric after it has been manufactured. Textile finishes convert a textile into a technical textile with functional properties. Usually, it is applied at the end of the textile processing. The reason for the increase in research and innovation in this sector is that it gives high performance along with the inherent textile property, which most importantly reduces the cost, makes it easily adaptable to the specific function and is more durable. There are three types of finishes: Chemical, Mechanical and Biotechnological. Mechanical finishes involve application through physical

principles like temperature, pressure, friction, heat, etc. Some examples of this method are calendaring, embossing, compacting, and sulfurising.

In the second method, i.e. Chemical finishes, the fibre or fabric is chemically treated to create a multifunctional textile. The application method includes coating, padding, exhaustion, spraying and foam application. A new method is recently being developed known as Nanotechnology which gives innovative functions such as self-cleaning properties which were not possible earlier. Sol-gel, Plasma enhanced chemical vapour deposition (PECVD), and Layer by layer (LbL), are some of the methods of application. Biotechnological finishes are the newest trend in the industry as they support sustainability by being environmentally, socially, and economically friendly. It makes use of enzymes to treat and modify the fibres. Enzymatic biopolishing, Bio Finishing for cotton, and Enzymatic hydrolysis are some of the examples.

The Textile finishes can broadly be classified into categories of -

- a. Finishes for improving comfort and performance, which are functional finishes for the fabric. They include thermal regulation, moisture management and soil release, softening, enzymatic bio finishes, shrink resistant, easy care, self-cleaning, superabsorbent, medical, cosmetic and aromatic finishes.
- b. The second category finishes for protection for both wearers or the fabric itself. It includes insect repellent, antimicrobial, hydrophobic, oleophobic, flame retardant, UV protection, radiation, antistatic, electrically conductive, biological, and chemical protection, ballistic and stab protection. These finishes raise a high concern regarding environmental issues and therefore require regulations to govern these finishes. (Paul,2015)

Flame retardant finishes

Flame-retardant finishes are a desirable functional finish in textiles in both cellulosic and synthetic fibre compositions. As natural fibres tend to ignite faster, synthetic fibres burn and melt with a chemical odour. Flame Retardants (FR's) are the chemical compounds applied on the surface of the fabric to either prevent or slow down the process of burning. The need for FR dates back to Roman times, where they used Asbestos. Asbestos fibres have been heavily used in industry since World War II to the present because of their durability, heat-resistance, and low cost. (Horrocks,2014)

Asbestos was a common FR used for many centuries until recently, when studies proved it is heavily linked to cancer, banning its use. Human diffuse malignant mesothelioma (DMM) has been linked to respiratory exposure to asbestos fibres. (Toyokuni,2009)

Flame-retardant chemicals have been incorporated into a wide range of items since the 1970s, furnishings such as carpets, beds, and seats, foam and coverings (even for transport vehicles), electrical and electronic gadgets, including televisions, phones, computers, and home appliances, materials for building and construction, including polystyrene foams, spray foams, and coatings for electrical lines and cables. The biggest usage of FR is in the apparel sector of firefighters, military, emergency personnel, kitchen apparel, and areas prone to fire require this clothing. In the USA, the Consumer Product Safety Commission (CPSC) requires that children's sleepwear be flame-resistant.

The Mechanism of Flame Retardants

The combustion process is an exothermic process which requires heat, oxygen and fuel known as exothermic process. The combustion cycle is shown in Figure 1. Below. Pyrolysis Temperature T_p is where the thermal decomposition of the fibre takes place and flammable gases such as carbon monoxide, hydrogen and non-flammable gases such as carbon, tar, carbon dioxide and water vapour are released. The flammable gases rapidly burn in contact with oxygen, which leads to reaching its combustion temperature T_c . With the heat energy and more generation of flammable gases, the intensity of combustion continues in the cycle. Therefore, the flame-retardant finishes prevent the fire from spreading or reduce the limiting oxygen index LOI of the fabric. Various mechanisms where flame retardants work are -

- By strong endothermic reactions, which absorb heat and prevent the stage of pyrolysis.
- Forming a glassy or foamy insulating layer on the surface to prevent further combustion.
- Altering the pyrolysis temperature of the fibre.
- Dilution of oxygen and flammable gases via inert or non-flammable gases.
- Interference of free radical reactions to avoid combustion.
- Intumescence which on burning forms an insulating layer of char and traps the gaseous materials.

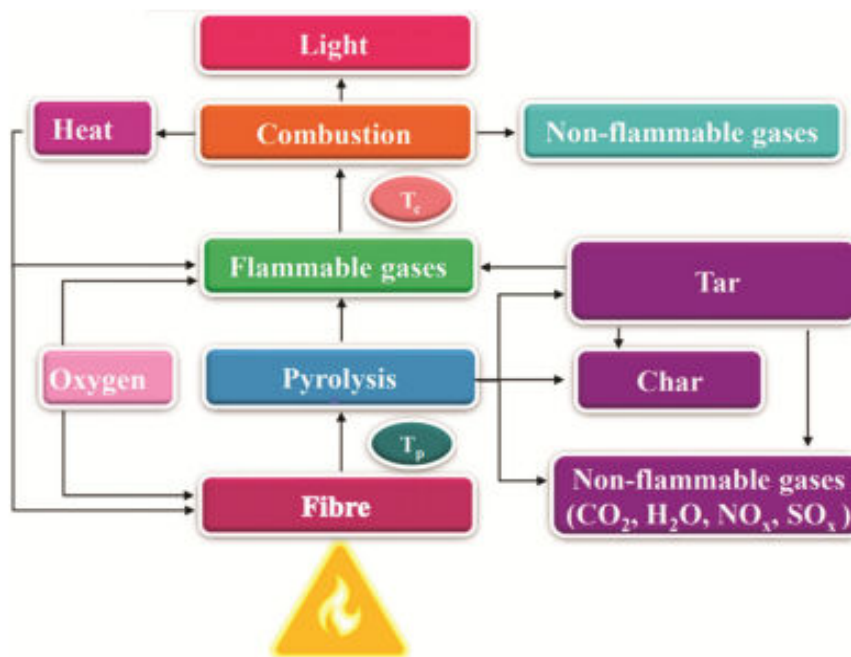


Figure 1. Combustion cycle. (Kakkar,2023)

There are various chemicals required in the use of Flame retardants, mainly categorised into inorganic FR's, halogen-based, phosphorus-based, phosphorus & nitrogen, borax and boric acid-based. (Kakkar,2023). The chemical composition of each compound is stated below –

- Inorganic Flame Retardants - aluminium hydroxide, aluminium trioxide, and magnesium hydroxide
- Halogen-based Flame Retardants - based on chlorine and bromine compounds like decabromodiphenyl or pentabromodiphenyl ethers, and polychlorinated biphenyls. Antimony is also used to give synergetic results. However, these are banned due to increased toxicity, persistence and being bio-accumulative, which are hazardous to nature.
- Phosphorus-based or Organo-phosphates Flame Retardants - these are divided into inorganic, organic, and halogen-containing categories. Ammonium polyphosphate and red phosphorus are used. These compounds are also environment-persistent, bio-accumulative, and possess various ecological risks and are also responsible for eutrophication and pollution. They release formaldehyde, known as a carcinogen and pose a risk to health and the environment.
- Phosphorus and Nitrogen-based Flame Retardants - Pyrovatex (N-methylol phosphono propionamide derivatives) and Proban (hydroxymethyl phosphonium salts) are used on

cellulosic fabrics. These treatments are expensive, non-eco-friendly, and require a high curing temperature.

- Borax and Boric Acid-Based Flame Retardants - A thick layer of boron trioxide is formed, which insulates and prevents the textile substrate from burning. But these, too, are not in use as they release formaldehyde and are non-environmentally friendly.

Due to such high potential risks of the chemical compounds, there is constant research exploring the potential technologies to reduce the adverse effects. Nanotechnology is the use of nanoparticles embedded in the fibre or fabric stage. It provides an efficient alternative to the traditional finishes. Some of the compounds used in Nanotechnology flame retardant finishes are

- Montmorillonite - a nano clay particle chemically hydrated with sodium, calcium, aluminium, magnesium & silicate hydroxide. These are eco-friendly but not very effective.
- Zinc Oxide Nanoparticles - polycarboxylic acids, such as butane tetracarboxylic acid (BTCA), succinic acid, and sodium hypophosphite (SHP) are applied on cellulosic textiles but show yellowness in the fabric.
- TiO₂ and SiO₂ Nanoparticles, along with Chitosan and Phytic Acid - has disadvantages on the fabric such as stiffness and loss of elastic properties.
- TiO₂ Nanoparticles, along with Proteins - have concerns with toxicity. (Kakkar,2023)

The recent advances are seen by the layer-by-layer (LbL) technique, where layers of thin film are built by electrostatic interactions. The drawback of this technique is that many layers are required for the finish to be effective, but it may result in stiffness of the fabric and reduced durability over time. Plasma-Assisted is also known as waterless finishing, and many experiments are done to form permanent coatings, especially for cotton textiles. However, it showed poor reproducibility, and the process is expensive.

In the last 5-10 years, studies have essentially been carried out to obtain eco-friendly biomolecules, either extracted from plants (grains and sap-based) or animal (polysaccharides or proteins based) natural sources for producing flame retardant textile material. Chitosan, deoxyribonucleic acid, whey proteins, caseins & hydrophobins, chicken-feather protein, banana pseudostem sap, phytic acid, green coconut shell (CSE), nucleic acid, tannic acid, pomegranate peel extract, tea stem waste, bio-based flavonoids with metal salts and grape skins

and seeds are some of the natural materials experimented for flame retardancy. Amongst the natural materials, Spinach Extract on cotton exhibited highest Limiting Oxygen Index (LOI). (Kakkar,2023)

Spinach Extract on Cotton

Comprehensive research by Basak et.al, 2017 has been conducted on cellulosic cotton textiles using spinach extract. The spinach juice was extracted from the leaves and filtered, and an alkaline solution was made. This extract was later applied to the fabric using the exhaust method on bleached and pre-mordanted with alum and tannic acid cotton fabric of 2000 gsm count. After the treatment, standardised tests were conducted for flame retardancy, fastness properties such as rub, wash and light fastness and physical properties of tensile strength and stiffness. Furthermore, SEM and EDX analysis gave results of the chemical compounds in the fibre content. Spinach has a high mineral salt content of phosphate, nitrates, silicate, magnesium, and chloride in the fabric, which are natural flame inhibitors. Since eco-friendly, natural compounds are used, there is no hazard to health, nor is the fabric damaged. The flame retardancy tests gave excellent results. The treated fabric and control fabric, i.e. untreated fabric, were measured. The LOI of cotton textiles is 18, whereas the Spinach-treated fabrics exhibited LOI - 30. The burning test results were also conducted, and it was seen that cotton fabric ignited and burned within seconds; however, the treated fabric caught the flame after 5 minutes and with slow burning. Spinach juice, when burned, acts as an intumescent layer on the surface of the cotton fabric, which, when burned, forms a char and ends pyrolysis. However, there are certain limitations which are common to all natural compounds concerning durability and fastness properties. The extract exhibited poor light fastness; the rub and wash fastness decreased after certain cycles, however, the physical properties remained undeterred. This is where AI plays a major role in bridging the gap between sustainability and functionality, which will be discussed further in this paper. (Basak,2017)

Antimicrobial activity on textiles

Antimicrobial finishes in textiles have been a practice since ancient times. Early evidence shows Egyptians using herbs and spices on cotton to prepare mummy wraps, and the Chinese using bamboo-Kun, bamboo fibres for housing structures. In India, Ayur Vastra- meaning health cloth in Sanskrit was used during the Vedic period. Thus, the practice of antimicrobial textiles dates to thousands of years. However, it has gained a lot of importance in recent years,

too, with the need for protective textiles. Its use is quite diverse, from innerwear, household apparel to fabrics used in harsh temperatures, it has become a necessity. Its use started in the era of World War where antimicrobials were needed to prevent infection of the apparel, rotting of fabrics used in tents, truck covers, tarpaulins from heavy rain and snow. With the growing industrial sector, the application increased in this sector, and the topmost priority was always in the medical textiles. The daily apparel, especially the innerwear's poses infections due to the excretion of body fluids, leading to fibre damage and odour. Thus, antimicrobial agents prevent undesirable effects such as degradation, colouring, staining, deterioration of fibres, odour, and other health risks. Therefore, Antimicrobial textile finishes paved the way for sanitary wear, sportswear, undergarments, winter wear, caps, jackets, upholsteries, mattresses, pillows and their covers, carpets, military uniforms, tents and in the medical sector, right from bandages to textiles used in hospitals has high importance. (Gulati,2022). Figure 2 depicts the antimicrobial activity.

Mechanism of antimicrobial finish

The antimicrobial finish has three mechanisms they work -

1. The controlled release mechanism - The antimicrobial agents are embedded in the fabric and released when any microbial activity is detected.
2. Regeneration mechanism - after neutralising the pathogens, the agents are regenerated again, making it durable for a long time.
3. Barrier or blocking mechanism - the textile substrate is modified to create a physical barrier. (Afraz,2019)

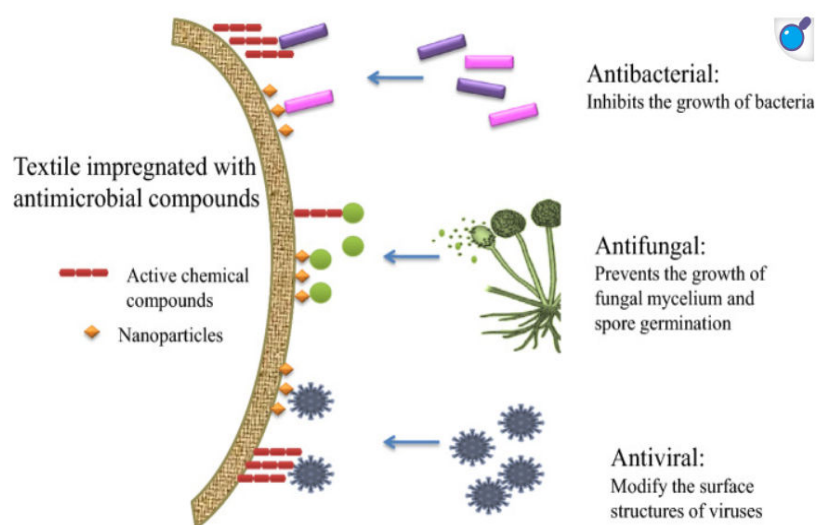


Figure 2. Antimicrobial Activity (Gokarneshan,2017)

Antimicrobial agents can be specific to the functions, such as antibacterial, antiviral, or antifungal. These agents are mainly divided into their ability to leach in the fibre or cause physical modification, commonly known as leaching and non-leaching types. The chemicals used in the antimicrobial agents are quaternary ammonium compounds, triclosan, metal salts, and polybiguanides. (Morais, 2017)

The Types of Antimicrobial Finishes

The types of antimicrobial finishes are -

- Organic antimicrobial agents which include quaternary ammonium compounds (QACs), N-Halamines, Polyhexamethylene Biguanide (PHMB); triclosan, silicon-based quaternary agent, phenols and thiophenols, heterocyclics, inorganic salts, nitro compounds, urea, amines, and formaldehyde derivatives.
- Inorganic antimicrobial agents - metal oxides, copper and zinc, titanium, magnesium, silver, and gold.

Although these compounds exhibited good antimicrobial activity, they had poor wash fastness and had ill effects on health, skin, and the environment. Natural antimicrobial agents such as neem, aloe vera, ginkgo biloba, and many medicinal plants exhibited antimicrobial activity. (Joshi,2009)

Antimicrobial activity on cellulosic textiles using Spinach extract

Research on the application of an eco-friendly antimicrobial finish using spinach extract on cotton showed the presence of antimicrobial activity. AATCC 147 test was done using agar diffusion method for E. coli and S. aureus bacteria. The variation of methods was in the application and the type of extract. Dried spinach leaves powder and spinach juice were extracted and applied through the exhaust and pad dry cure method on cellulosic textiles. The method of application of pad-dry-cure with dried powder extract showed better results. The visual burning test provided results of flame retardancy. This research was an extension of the previous research on flame-retardant spinach fabric to prove multiple functions from one natural extract. Also, the versatility, easy application and economical factor of natural finishes make them applicable in most of the products and therefore become necessary for sustainability. (Thanawala,2021)

Limitations of the finishes on textiles

The fabric from the stage of fibre to garment making is subjected to many harsh treatments, both physically and chemically. The final stage of the textile processing is the application of finishes. As stated above, several finishes are required, and at times multiple finishes are applied on one single garment. The chemicals present in the finishes have harmful effects on the skin, the environment, and the textile substrate as well. The finishes on textile substrate possess 3 challenges -

Application - Either natural or chemical finish; do not naturally adhere to the textile substrate and therefore require treatment of the fabrics.

Retention - The natural finishes exhibit the difficulty of adhering to the textiles more than the chemical finishes. Due to laundering, exposure to sunlight and constant tension or friction to the fabric tends to lose its functionality. (Kakkar,2023)

Reaction - Although the tests are done prior to the application of the finish, during the fabric life cycle, there are various interactions with other chemical components which alter the composition. It can occur during washing, which has detergents, softeners, bleaches, antioxidant agents, or bodily excretions themselves.

Therefore, natural finishes do serve as an eco-friendly alternative, but the major reason it is not used in major industries is because of the durability of the finish. Hence, we further explore the possibilities in the current scenario of integrating AI in the textile finishing industry.

AI in Textile Industry

Definition of AI

Artificial Intelligence is a machine's ability to perform some cognitive functions usually associated with human minds. Examples include brain-specific cognitive functions like perceiving, reasoning, learning, interacting with the environment, problem solving and performing human tasks like creative thinking. (McKinsey,2025)

With AI, several possibilities can be explored which were once hindered by human, resource and time and space limitations. The textile manufacturing industry, being one of the highest polluting industries, is also labour-intensive and requires significant fixed capital investment. It is distinguished by a diverse range of product designs, leading to varied input materials,

fluctuating production volumes, intense market competition, and stringent quality standards. (Welamo,2023)

There are several techniques and approaches of AI shown systematically in the Figure. 3. A detailed research in the approaches with its advantages and limitations was conducted, and an insight into where it can be applied in the textile industry was shared. For example, ANN can be used for the prediction of the properties, analysis of textile defects, process optimisation and marketing and planning. (Shamey,2003)

The evolution of artificial intelligence

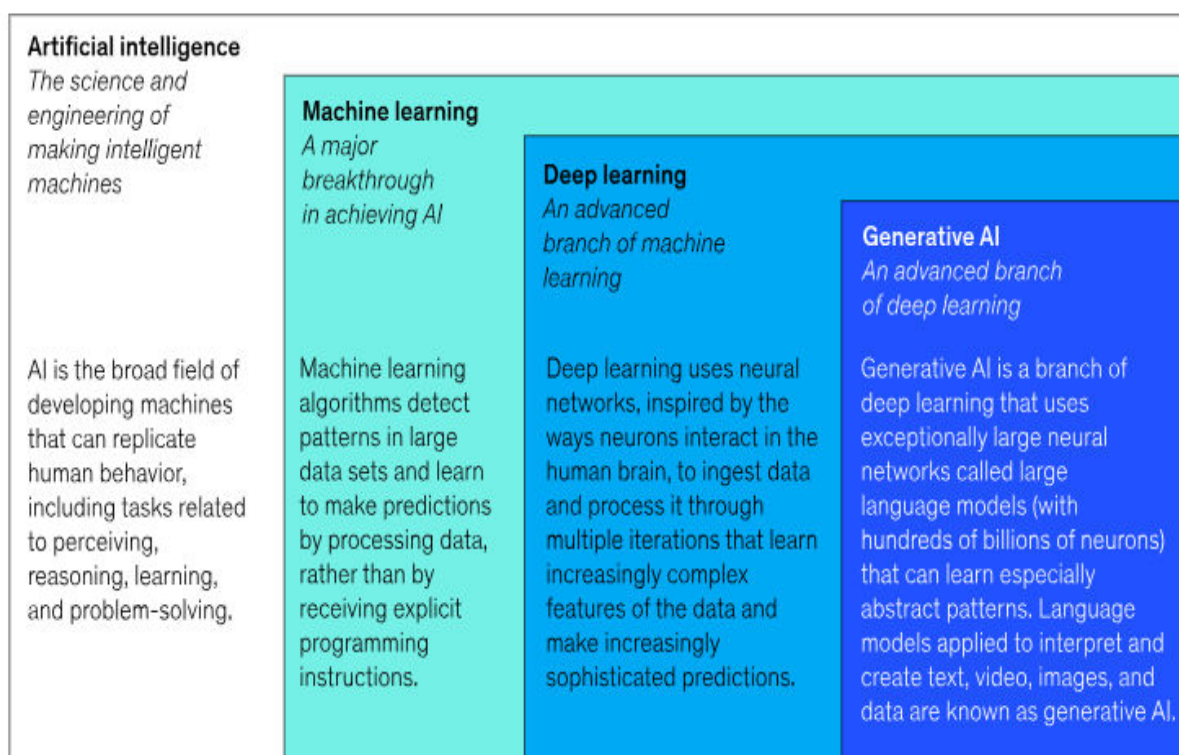


Figure 3. The evolution of AI (McKinsey,2025)

AI in the Textile Industry

In the textile industry, AI can help in the optimisation of the production, analysis, regulation, control, and detection of various processes, and improvement in quality and innovation can help lead a new path.

AI plays a vital role in various stages of textile production, including fibre grading, yarn property prediction, fabric fault detection, and dye recipe formulation. Similarly, it can be integrated into every phase of garment production, from preproduction to production and postproduction processes. Fabric defects can significantly diminish the value of textile

products. To address this issue, AI techniques like Artificial Neural Networks (ANN) are employed for defect detection during fabric inspection in the textile industry. (Welamo,2021)

AI enables machines to process and analyse large volumes of data to execute tasks and streamline processes. In textile manufacturing, AI is utilised in multiple areas, including colour matching, colour recipe formulation, pattern recognition, garment production, process optimisation, quality control, and supply chain management. These applications contribute to increased efficiency, improved product quality, enhanced competitiveness, minimised environmental impact, and a better customer experience. As machine learning algorithms become more advanced and computing power continues to grow, the role and effectiveness of AI in the industry are expected to expand further. (Kistamah, 2024)

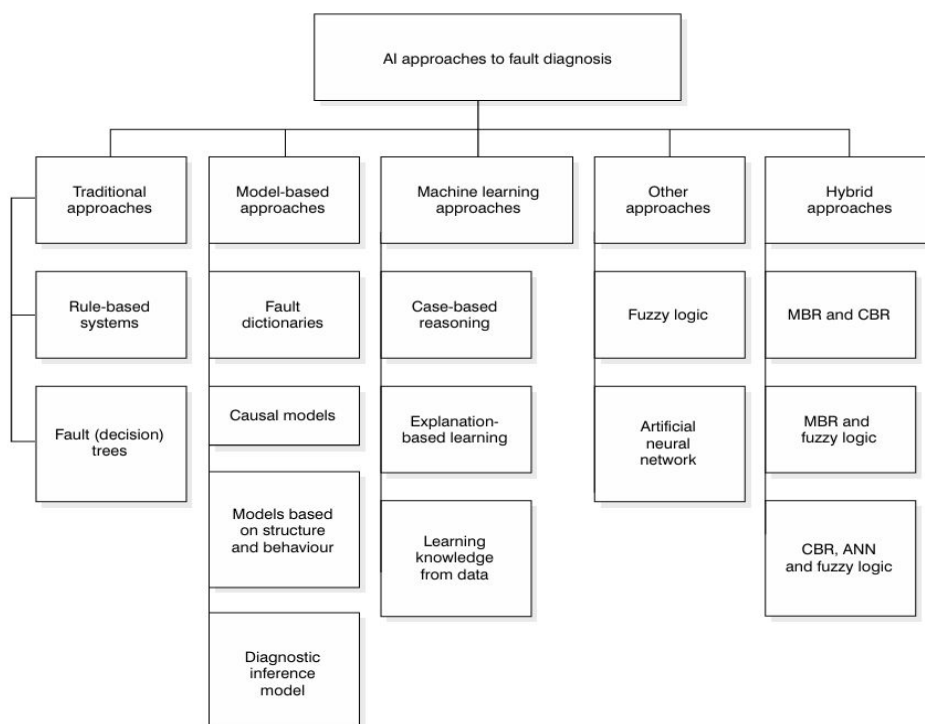


Figure 4- AI Approaches (Shamey, 2023)

AI in Flame Retardancy

Enhancing the flame retardancy of polymeric materials used in engineering applications is becoming increasingly essential for reducing fire risks. However, the wide range of flame-retardant polymeric nanocomposite formulations makes it challenging to quickly identify the optimal design for a particular application. Research studied 800 nano polymers and applied five machine learning algorithms to predict the flame retardancy index of various flame-

retardant polymeric nanocomposites, where the most accurate prediction was achieved with a coefficient of determination (R^2) of 0.94 and a root-mean-square error of 0.17. Based on these insights, a high-performance flame-retardant polymeric nanocomposite and the experimental flame retardancy index (FRI) were designed and synthesised and compared to the machine learning prediction, showing only a 6% prediction error. This experiment was essential as time and cost regarding extensive fire testing were assessed quickly with accuracy. (Zhang,2022)

AI for Antimicrobial Activity

For antimicrobial activity, a brief review has been conducted on the use of AI for antimicrobial resistance (AMR) in the health sector. Although this research does not serve for textiles, its application is widely inspiring to incorporate. AI applications have been used to study AMR by sequencing-based applications. Some of the most used AI algorithms for AMR, including Naïve Bayes (NB), decision trees (DT), random forests (RF), support vector machines (SVM), and artificial neural networks (ANN) were reviewed. (Deng,2021)

AI for Cotton Pest Control

Integrated Pest Management (IPM) aims to reduce the environmental impact of pesticides and minimise risks to human and animal health by AI-based detection and diagnosis of diseases and insect pests in cotton. It is built on two key principles: prevention and monitoring of diseases and insect pests, which are increasingly supported by sensing technologies and artificial intelligence (AI). Commonly used algorithms include support vector machines, fuzzy inference systems, back-propagation neural networks, and, more recently, convolutional neural networks. For image segmentation, k-means clustering was the most frequently applied technique, while feature extraction methods commonly involved the histogram of oriented gradients, partial least squares regression, discrete wavelet transforms, and enhanced particle swarm optimisation. Among sensing techniques, cameras, and environmental sensors, such as temperature and humidity sensors, were widely employed. The most frequently studied insect pest was the whitefly, while root rot was the most investigated disease. The findings indicate that AI techniques have primarily been utilised for (i) classification, (ii) image segmentation, and (iii) feature extraction. (Toscano, 2023)

Conclusion

AI has indeed become a revolutionary technology which has significantly reduced the time and resources. There is much research in the field of AI to overcome the challenges. However, for the implementation of the research, such a diverse field of AI needs skilled labour and resources. To conclude, AI can help to reduce the limitations of the natural materials of the fabric and finishes, where the main issue is with regards to durability. This, with the AI systems of detection and regulation of the finishes on fabric and timely application, may indeed be a viable option for overcoming the limitations and an important step to move towards sustainability.

References

- Raja, A. S. M. (2021). *Business research in the VUCA world (Volatility, Uncertainty, Complexity, and Ambiguity)*. *Ushus - Journal of Business Management*, 20(1), v–xvi.
- Wright, G., & Wigmore, I. (n.d.). What is VUCA (Volatility, Uncertainty, Complexity and Ambiguity) *TechTarget*. Retrieved [02/2025], from <https://www.techtarget.com/whatis/definition/VUCA-volatility-uncertainty-complexity-and-ambiguity>
- Luo, Y., Song, K., Ding, X., & Wu, X. (2021). Environmental sustainability of textiles and apparel: A review of evaluation methods. *Environmental Impact Assessment Review*, 86, 106497. <https://doi.org/10.1016/j.eiar.2020.106497>
- Firechief Global. (2024, January 25). 12 causes of fire in the home. *Firechief Global*.
- Pelzman, J. (1982). The Textile Industry. *The Annals of the American Academy of Political and Social Science*, 460, 92–100. <http://www.jstor.org/stable/1044601>
- Thanawala Nafisa J. (2021). Application of eco-friendly antimicrobial finish using spinach extract on cotton. *Proceedings of the International Conference on Sustainable Growth in Textiles, 2021*. Department of Textile and Fashion Technology, College of Home Science, Nirmala Niketan, Mumbai.
- Horrocks, A. R. (2014). High performance textiles for heat and fire protection. In *High performance textiles and their applications* (pp. 144-175). Woodhead Publishing. <https://doi.org/10.1533/9780857099075.144>
- Paul, R. (2015). Functional finishes for textiles: an overview. *Functional Finishes for Textiles, Improving Comfort, Performance and Protection*, 1-14. https://www.niehs.nih.gov/health/topics/agents/flame_retardants
- Toyokuni, S. (2009). Mechanisms of asbestos-induced carcinogenesis. *Nagoya journal of medical science*, 71(1-2).

Kakar, P., Singh, A., & Sheikha, J. (2023). *Department of Textile and Fibre Engineering, Indian Institute of Technology Delhi, New Delhi 110 016, India*. Manuscript received July 14, 2022; revised and accepted June 1, 2023.

Gulati, R., Sharma, S., & Sharma, R. K. (2022). Antimicrobial textile: Recent developments and functional perspective. *Polymer Bulletin*, 79(8), 5747–5771.
<https://doi.org/10.1007/s00289-021-03826->

Gupta, Deepti & Bhaumik, Somes. (2007). Antimicrobial treatments for textiles. *Indian Journal of Fibre & Textile Research*. 32. 254-263.

Basak, S., Samanta, K. K., Saxena, S., Chattopadhyay, S. K., & Parmar, M. S. (2017). Self-extinguishable cellulosic textile from Spinacia . *Indian Journal of Fibre & Textile Research (IJFTR)*, 42(2), 215-222.

Gokarneshan, N., Nagarajan, V. B., & Viswanath, S. R. (2017). Developments in antimicrobial textiles-some insights on current research trends. *Biomed. J. Sci Tech. Res*, 1, 230-233.

Rouhani Shirvan, A., Shakeri, M., & Bashari, A. (2019). Recent advances in application of chitosan and its derivatives in functional finishing of textiles. In S. Islam & B. S. Butola (Eds.), *The impact and prospects of green chemistry for textile technology* (pp. 107-133). Woodhead Publishing. <https://doi.org/10.1016/B978-0-08-102491-1.00005-8>

Morais DS, Guedes RM, Lopes MA. Antimicrobial Approaches for Textiles: From Research to Market. *Materials* (Basel). 2016 Jun 21;9(6):498. Doi: 10.3390/ma9060498. PMID: 28773619; PMCID: PMC5456784.

Nayak, R., & Padhye, R. (2014). *Antimicrobial finishes for textiles* (pp. 361-385). Woodhead Publishing: Cambridge, UK.

Afraz, N., Uddin, F., Syed, U., & Mahmood, A. (2019). Antimicrobial finishes for textiles. *Current Trends in Fashion Technology & Textile Engineering*, 4(5).
<https://doi.org/10.19080/CTFTTE.2019.04.555646>

Joshi, M., Wazed Ali, S., Purwar, R., & Rajendran, S. (2009). Ecofriendly antimicrobial finishing of textiles using bioactive agents based on natural products. *Indian Journal of Fibre & Textile Research*, 34(3), 295-304.

Kistamah, N. (2024). *The applications of artificial intelligence in the textile industry*. In *Artificial intelligence, engineering systems and sustainable development*. Routledge. <https://doi.org/10.1201/9781837535408>

Zhang, Z., Jiao, Z., Shen, R., Song, P., & Wang, Q. (2022). Accelerated design of flame-retardant polymeric nanocomposites via machine learning prediction. *ACS Applied Engineering Materials*, 1(1). <https://doi.org/>

Welamo, T., & Sanpeng, D. (2021). Application of artificial intelligence in the textile industry. *Journal of Emerging Technologies and Innovative Research (JETIR)*, 8(10), d49. Retrieved from <https://www.jetir.org>

Mostafa, Elkhaoudi & el Bakkali, Mohammed & Redouane, Messnaoui & Cherkaoui, Omar & Aziz, Soulhi. (2024). Literature review on artificial intelligence in dyeing and finishing processes. *Data and Metadata*. 3. 360. 10.56294/dm2024360.

Liv, J., Deng, S., & Zhang, L. (2021). A review of artificial intelligence applications for antimicrobial resistance. *Biosafety and Health*, 3(01), 22-31.

Toscano-Miranda, R., Toro, M., Aguilar, J., Caro, M., Marulanda, A., & Trebilcok, A. (2022). Artificial-intelligence and sensing techniques for the management of insect pests and diseases in cotton: A systematic literature review. *The Journal of Agricultural Science*, 160(1-2), 16-31.

Shamey, R., & Hussain, T. (2003). Artificial intelligence in the colour and textile industry. *Review of Progress in Coloration and Related Topics*, 33, 33-45.

Climate Change, Coastal Vulnerability, and Community-Based Resilience: A Case Study

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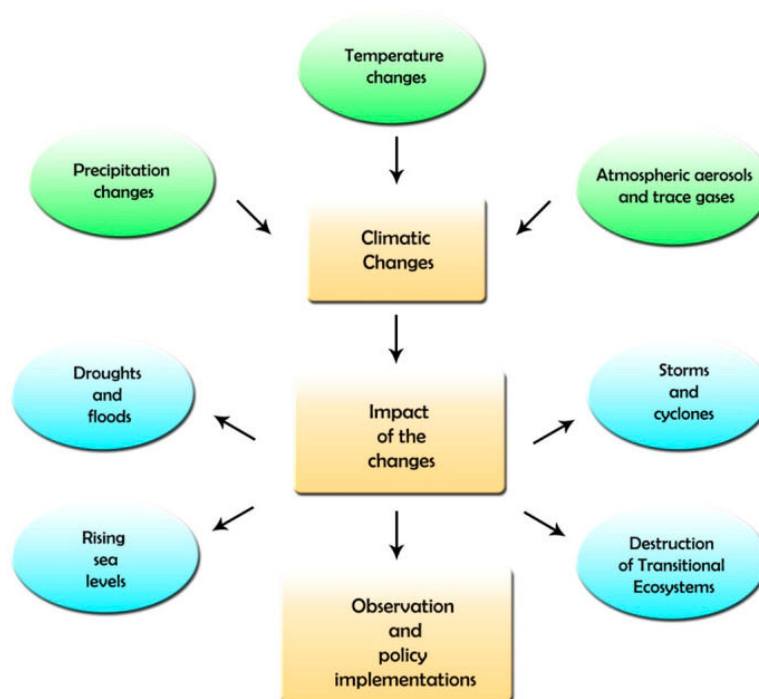
Abstract

Global warming and consequent climate change is causing severe weather events, disasters, habitat destruction, and livelihood impacts on Earth. Since 1880, global sea levels have risen 8-9 inches due to global warming, leading to glacier melting and ocean warming (Lindsey, 2022). By the end of the century, sea levels are expected to rise at least one foot. To combat climate change, local solutions include reducing carbon emissions, adjusting heat absorption profiles, and planting saplings to maintain cooler environments. Alappuzha, Kerala's only district free from mountain calamities, faces recurring soil erosion and rising sea levels due to climate change, and 95% of its 82 km coastline is under threat (Jennath, 2024). Community-based initiatives play a crucial role in enhancing the effectiveness of climate change adaptation strategies in coastal areas by empowering local communities, leveraging indigenous knowledge, and fostering sustainable practices. *Chethy* beach in Alappuzha is preparing for landslide threats with local fences and *Casuarina Equisetifolia* saplings planting, while coastal mangroves prepare for tsunamis and other marine crisis situations. The study evaluates global warming's local effects on sea level changes and soil erosion, assessing the importance of coastline afforestation using mangroves as organic fencing. Results show mangrove and *Casuarina Equisetifolia* fencing effectively manages rough sea, landslides, and soil erosion and was even effective during the 2004 tsunami and subsequent *Ockhi* cyclone event.

Keywords - Global Warming, Climate Change, Soil Erosion, Sea Level Changes, Organic Fencing, Coastline

Global warming refers to the long-term rise in the average temperature of the Earth's climate system, primarily due to the increased concentrations of greenhouse gases such as carbon dioxide, methane, and nitrous oxide in the atmosphere. The catastrophic weather events and global warming are some most dangerous threats to human life on Earth, and they all have one thing in common: they are all man-made. Climate change is causing severe weather events, disasters, habitat destruction, and livelihood impacts. It is causing increased fires, food security challenges, and unrelenting heat, with urban heat being the top cause of weather-related casualties around the globe. A new World Economic Forum report warns that climate-intensified natural disasters may cause \$12.5 trillion in economic losses and over two billion healthy life years lost by 2050 (Climate Crisis May Cause 14.5 million Deaths by 2050, n.d.). The climate disaster will exacerbate global employment and health disparities, placing vulnerable communities at risk.

Figure 1: Global Warming, Conceptual Analysis



Source: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10113820>

The conceptual understanding of global warming, its causes, and its impacts is summed up in Figure 1 above. With fossil fuels like coal, oil, and gas producing 90% of carbon dioxide emissions and 75% of greenhouse gas emissions, these sources are the main causes of climate change (Causes and Effects of Climate Change | United Nations, n.d.). Climate change is also caused by the mining, building, and manufacturing industries; deforestation; transportation;

food production; and the use of commodities in homes and businesses. Because of their large contribution, industrialized nations ought to shoulder the most of the blame. Climate change caused by global warming has resulted in higher temperatures, stronger storms, droughts, and ocean warming. Because of its twofold increase in temperature over the global norm, the Arctic now experiences more heat-related illnesses and strong storms. Destructive storms are becoming more common and powerful, causing extreme rainfall and flooding. The ocean absorbs the majority of the heat caused by global warming, threatening coral reefs and marine life.

Climatic changes are visibly felt in a country like India, which holds vast stretches of coastland, governed by its latitudinal location (between latitudes 8° N and 37° N), peninsular shape, water bodies - Bay of Bengal (on the eastern side), Indian Ocean (in the southern region), and Arabian Sea (on the western side), encompassing the extensive coastlands (nearly 7500 km), which influence rainfall, monsoon winds, air currents, and tropical cyclones (Wilson et al., 2020). According to research (Simrin Sirur, 2024), evaluating the risk of disasters along Kerala's central coast, storm surges, cyclones, and coastal erosion are among the threats that the region faces. Punnapra, Ambalappuzha, Chethy, Arthunkal, Chellanam, and Kuzhupilly were identified in the study as "very high-risk zones" because of characteristics including high population density, built-up area, frequency of surge events, and high rainfall.

Sea levels are rapidly rising, and present protocol solutions are only useful after a crisis strikes as relief efforts to save lives, protect impacted coastal districts by lessening the risk of devastation, making reconstruction easier, or making living with the condition acceptable. In addition to post-disaster assistance measures, the coastal area requires infrastructure precautions such as sea barriers, elevated roads, and nature-based prevention measures to deal with sea-borne disasters. Sea walls are constructed along the coastline to prevent flooding, erosion, and storm surge. However, these barriers must be maintained indefinitely and may exacerbate floods in places beyond the wall's protection. Nature-based initiatives include preserving natural coastal defences, which can help to mitigate the effects of sea level rise and support coastal populations. It is critical that affected areas be protected by mangroves, seagrasses, salt marshes, and oyster beds, which can provide recreational activities, food, and other community benefits.

The research problem is therefore defined as "precautionary measures against sea level changes and its effects on coastal area of *Chethy* beach of Alappuzha district," which includes

"mangrove sapling planting at strategic points and other participatory programs for awareness and local actions to manage the increasing threat of sea level rise in the region," as well as large-scale awareness campaigns among the coastal people.

Methodology

Anthropogenic climate change is a serious threat to the existence of humans on Earth, with consequences for global food supplies, crop yield, sea level rise, and habitat loss. Numerous attempts are being made under the UNO's initiative to minimise the effects of global warming; democratic approaches are the most effective, and collective measures are also effective. The study is designed using a field-based research technique of sociology and anthropology in order to evaluate the efficacy of collective social measures to minimise the extreme effects of global warming-related sea level changes. The study's objectives include

- To evaluate how sea level rise has affected the shoreline
- To evaluate how well mangrove fencing at *Chethy* Beach protects the shoreline and lessens erosion.
- To look into how mangrove fencing improves the ecological and biodiversity of the shore.
- Analyse the socioeconomic disparities that local communities face, taking into account livelihood support and climate change resistance.

The research framework consists of

- a) Study Location: Alappuzha, Kerala, India's *Chethy* Beach
- b) Field Observations: Make routine field trips to keep an eye on the mangrove fencing, gather information on the pace of erosion, and note any changes to the coastal habitats.
- c) Gathering of Data: Primary data sources include surveys on socioeconomic advantages and difficulties as well as interviews with stakeholders, fishers, and local populations.
- d) Secondary data: An analysis of the body of research on the effects of climate change, mangrove fencing, and coastal management techniques.

Data analysis includes the study of the experimental design as well as quantitative and qualitative analysis. The quantitative analysis included socioeconomic data, biodiversity indices, and erosion rates, statistically analysed. Thematic analysis of survey replies and interview transcripts is a component of qualitative analysis. To evaluate the efficacy of mangrove fencing, the experimental design involved comparing coastal areas that were fenced

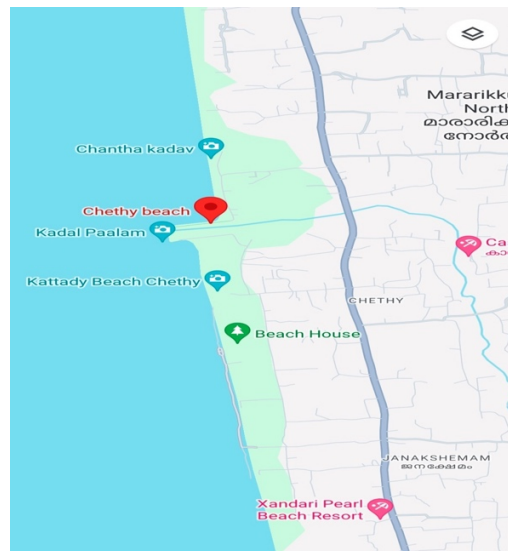
and those that weren't. In terms of sampling strategy, a random sampling of stakeholders, fishers, and local populations is used for surveys and interviews.

This is only the beginning; further research with more complex goals and methods to fit in with in-depth and targeted studies is advised. Because the study is focused on a certain location and examines particular elements, it has limitations.

Study Area

One of the most popular tourist destinations in the Alappuzha area is *Chethy Beach*. In close proximity to the seashore lies the well-known pilgrimage site, *Arthunkal Basilica*. The beach is reachable via a system of roads, and a state highway passes right by it.

Figure 2: Study Cite Map



Source: Google Maps

The 4.86 km long coastline area is susceptible to many natural disasters such as regular soil erosion, shoreline slippage, and sea turbulence. The monsoon season is when sea turbulence peaks, and the impacted area on the coastline is indicated by the green mark on the map (Figure 2). A significant portion of the population makes their living from fishing and associated occupations; employment in agriculture, coir production, and related fields is also important. In terms of educational attainment, those over 60 had only completed the eighth grade, those in their 50s had completed matriculation, and those under 40 had completed higher education. The percentages were as follows: 3% of people were illiterate, 18.5% of people had attended

school but did not graduate, just 22% had done so, 43.9% had completed higher education, and 7.1% had technical education.

These fishermen deal with a variety of socio-economic issues that affect their everyday life, despite playing a vital part in the local economy. Even though they had difficulty fishing in the choppy Arabian Sea, the expense of climate change severely hampered their socioeconomic situation. Harsh sea conditions, erratic income, restricted resource access, occupational dangers, and a lack of education and skill development are the socioeconomic obstacles. They encounter workplace risks, find it difficult to compete with larger businesses, and are not provided with social security benefits like health insurance, unemployment benefits, or pension plans. These elements impede their capacity to adjust to evolving fishing methods and exacerbate their socioeconomic difficulties.

Recently started community support will assist fishermen in overcoming personal and financial obstacles. It was suggested that people diversify their sources of income by taking up supplementary employment in the tourism, agricultural, or fish processing industries. The Arabian Sea is experiencing major changes due to climate change and global warming, which are having an impact on marine life, fish populations, and ocean currents. While rising CO₂ levels are generating ocean acidification, rising sea temperatures and ocean currents are changing fish distribution and abundance. Fisheries and coastal communities are also impacted by cyclone frequency and intensity. Changes in species composition are causing fish populations to decline, and the economy of coastal communities and fishermen are being impacted by climate change. The frequency and power of recurrent cyclones are rising, endangering ecosystems, fisheries, and coastal infrastructure. In addition to damaging human settlements, agriculture, and fisheries, these cyclones also result in food insecurity, economic losses, and displacement. Furthermore, the coastal ecosystems that provide vital homes for marine life, such as mangroves, coral reefs, and seagrass beds, are being disrupted by cyclones.

Analysis of the Major Shoreline Issues

Kerala's coastal regions—particularly Alappuzha—are under crisis as a result of overexploitation of resources such as coastal sand, mangroves, fisheries, and land area, as well as tourism-related building and local population relocation. Many companies, both large and small, can be found in the coastal zone, and they all directly discharge wastewater into the marine environment. In order to draw in foreign tourists, the private resorts along the coast erected enormous, traditional houses. To do this, they bought out locals and drove the fishermen

out of the area. Fishing and other activities by fishermen were forbidden on the resort's sunbathing beachside, and these resort constructions have accelerated coastal erosion. The only area where homes are periodically lost to erosion is the coastal community. The situation is made worse by the removal of natural ecosystems, such as wetland reclamation and mangrove cutting. The unparalleled scope of sand extraction for commercial and residential uses poses a serious risk to the coastal ecosystem.

Table 1: Summary of Shoreline Issues in Alappuzha

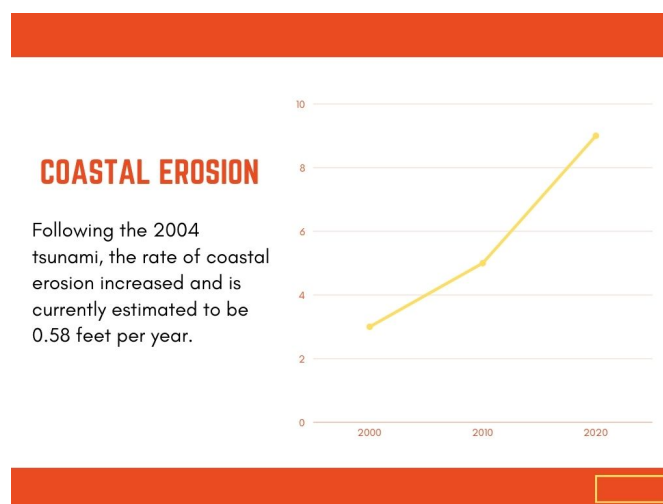
Issue	Description	Dimension
Coastal Erosion	Coastal erosion brought on by both human activity, such as sand mining and coastal development, and natural processes, such as tides, waves, and currents	73% Throughout the year. Natural as well as anthropogenic
Changes in Climate	While overfishing, habitat degradation, and climate change contribute to dwindling species populations, rising ocean temperatures and pH are having an impact on fish distribution, behaviour, migration patterns, capture rates, and fisheries management.	27% decrease in fish count. 1% increase in ocean temperature periodically. Chakara, a marine phenomenon where multiple fish and prawns gather in mud bank formations during a specific season, is decreasing (42%).
Coastal Regulation Zone (CRZ)	The Coastal Regulation Zone (CRZ) Notification regulates high-impact activities in the coastal zone, which negatively impacted the fishing population by placing tight restrictions on building houses.	26% fishermen migrated due to restrictions of CRZ 38% depreciation in house renovation or constructions
Sand Mining	Seashore land mining is of two kinds, for local constructions and for commercial mineral extraction.	Fishermen use 3% of the shoreline for sand mining in order for construction. Up to 13% of the coastline is intended to be used for mineral extraction.

Sea Wall	The study area's majority of homes, particularly poor fishermen's dwellings, were inundated with seawater, resulting in numerous residences being demolished. During the monsoon, sea erosion was continuous. The areas without any sea wall construction were the worst affected.	23% of fishermen's dwellings are in CRZ zone. Sea erosion was a persistent threat to 41% of dwellings.
Flooding	Coastal areas experience shoreline flooding even after the rainy season. The 'Kallakkadal' phenomena, in which the sea surges into land and causes floods, is another concern. The study region is one of the most severely affected locations.	6% of sea surges due to kallakkadal phenomena
Saltwater Intrusion	In the research area, saltwater intrusion into shallow coastal aquifers is a major problem. Using VES profiling, the depth of the fresh-saline water interface was measured along the study area.	Water quality parameters such as pH, TDS, salinity, total alkalinity, and formation salinity are known to vary seasonally.
Displacement	Displacements brought on by sea surges, floods, and other natural disasters, as well as the expansion of tourism developments along the shore, particularly in the study region	Narratives of abandoned houses, flooded areas, and uprooted populations dot study region, underscoring the pressing need to bring attention to these issues.
Seasonal Unemployment	The government's stance against mechanized fishing has led to increased unemployment, poverty, and livelihood issues. Trawl bans, implemented to recover resources, have exacerbated these issues, particularly in coastal fishing villages and affected food security.	income loss of 27% during the monsoon. 90% loss of employment while there was a trawl ban
Monsoon Turbulence	The southwest monsoon is causing turbulent seas along the Kerala coast, causing loss of lives and property, along with depression and other challenges.	23% of challenges on fishermen's life is caused by Monsoon Turbulence

Problems with the shoreline in the research region include mineral extraction along the shoreline, built-up areas, salt intrusion into lagoons, and erosion. 39.12% of Alappuzha's coastline eroded between 1973 and 2021; the study area in the south had the greatest rate of erosion, at 44.04%. Global processes that are dominated by the land and ocean have an impact on coastal zones, which are defined by gradient-dependent ecosystems, climate, geomorphology, human settlement, and dynamic physical, chemical, and biological processes (Gotz Hoeppe, 2007). They have historically supported biogeochemical cycling and ecosystem function. Nevertheless, tensions between short-term and long-term resource availability result in pollution and devastation.

There have been two significant natural catastrophes in the study area recently. A number of villages were impacted by the massive destruction and fatalities caused by the 2004 Indian Ocean Tsunami. Strong cyclone Ockhi from 2017 severely damaged fisheries, agricultural land, and coastal towns (Manorajan et al., 2020). Local communities, NGOs, and government organizations came together to offer assistance, support, and rehabilitation programs. Rescue efforts, food, housing, medical assistance, damage assessment, rehabilitation, and disaster mitigation measures were some of these endeavours. The intention was to lessen suffering and aid in the coastal region of Alappuzha's long-term recovery.

Figure 3: Costal Erosion in Alappuzha (Primary Source)



The study reveals that Kerala's average annual coastal erosion rate is 0.5-1.5 meters (1.64-4.92 feet) per year (Govt. of Kerala, 2016), with higher rates observed in certain areas. The study, from 2000 onwards, reveals that Chethy (Alleppey) experiences a high rate of 1.2-1.5 meters (3.94-4.92 feet) per year till 2020, which is significantly higher than other seashores in Kerala.

Fencing Using Mangrove: An Intimate Approach

The efficiency of mangrove and *Casuarina Equisetifolia* fencing along the beach as a coastal defence against floods, sea surges, and coastal erosion is being investigated in this study. In collaboration with the Social Forestry Department of the Local Self Government, the St. Michael's College National Service Scheme unit in Cherthala took the initiative to plant 5000 *Casuarina Equisetifolia* and 25000 mangrove saplings as part of an education campaign about the importance of mangrove fencing. By 2018, the afforestation effort had been completed, and the locals and volunteers had been caring for the plants' growth and hydration.

Picture 1: Temporary Sea Wall Construction by NSS Volunteers



Because mangroves naturally provide barriers against erosion, storm surges, and sea level rise, mangrove fencing is an effective method for controlling coastal erosion. Because of their extensive root systems, mangroves help to stabilize the soil and stop sedimentation and erosion.

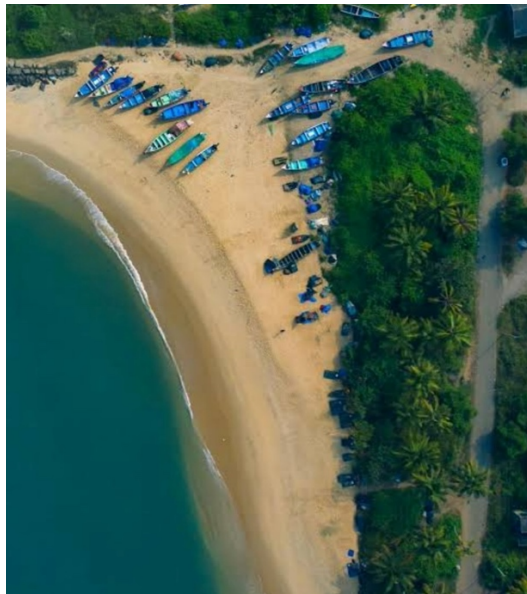
Picture 2: NSS Volunteers Planting Mangrove Saplings



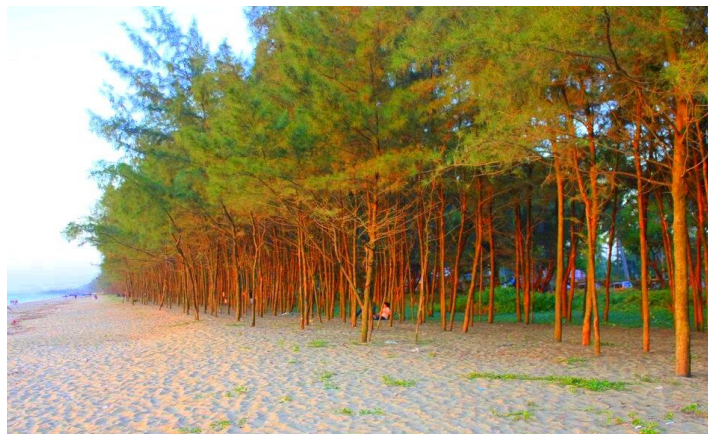
In order to reduce the effect of waves on the shoreline, they also have a wave attenuation system. Mangrove fencing contributes to coastline maintenance by stopping more erosion and land loss. Additionally, it captures silt, enabling it to build up and expand the shoreline. A natural defence against storms, surges, and sea level rise is provided by mangrove forests. Compared to seawalls, they require less maintenance, sustain fisheries, offer habitat for a variety of marine animals, and preserve the quality of the water. Mangrove fencing, however, needs to be carefully planned and erected in tandem with other coastal management techniques in order to prevent.

0.9 km of the shoreline is protected by mangrove fencing, while 1.7 km of the coastline is currently covered in bio-fence made of *Casuarina Equisetifolia*.

Picture 3: Mangrove Fencing at Chethy



Picture 4: *Casuarina Equisetifolia*, the Bio-fence at Chethy



Significance of bio-fencing on the seashore: Studies highlighted that mangrove bio-fencing is a crucial tool for seashore protection and ecosystem health. It reduces erosion by stabilising soil and absorbing wave energy, acts as a natural barrier against storms and sea-level rise, creates habitats for diverse marine life, improves water quality by filtering sediment and pollutants, and contributes to climate change mitigation by absorbing and storing carbon (Department of Fisheries, 2018). It also protects coastal infrastructure, agriculture, and human settlements, supports fisheries, tourism, and coastal livelihoods, is low maintenance compared to traditional coastal structures, helps adapt to climate change by providing resilience to extreme weather events, and maintains ecological connectivity between terrestrial and marine ecosystems. Overall, mangrove bio-fencing is a valuable tool for sustainable coastal management.

Due to its 590 km of coastline, which features mud and sand beaches, rock formations, lagoons, estuaries, barrier islands, and diminished coastal vegetation, Kerala faces a serious problem with coastal erosion. As a precautionary measure, the state government relocated vulnerable families along the coast and installed marine defences to increase the safety of those who live there (Rajan, 2019). The project's goal is to put into practice long-term coastal preservation strategies to lessen unresolved concerns related to sea level rise in populated regions. Tetrapods are advised as an appropriate safeguard for shoreline protection, and the government has made significant investments in tetrapod fencing around the coastline.

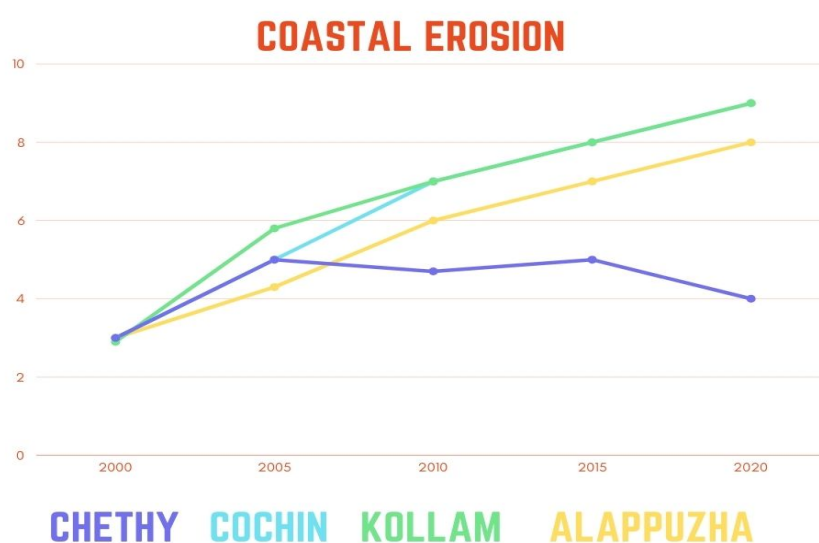
Picture 5: Tetrapode Fence (Source: Media Archive)



However, in numerous locations, the tetrapodes were unable to prevent soil erosion along the shoreline during the monsoon season. The tetrapode fence is broken by the tumultuous sea, strong winds, and heavy, stormy sea. Then, TetraPOT (special pots) encourage root development and plant growth because they are designed to withstand fluctuations in beach water levels. Its hollow construction collects water when grouped together, forming a natural mangrove (Clark, 2018). It is believed that the pot's weight helps stop soil erosion by forming above-ground walls and subterranean root systems. Tetrapots are now being used in place of tetrapodes. Mangroves and other natural bio-fences are therefore clearly more dependable and efficient than any other kind of defence against shoreline erosion.

Mangrove bio-fencing at seashores enhances coastal resilience, improves biodiversity, reduces wave energy, and stabilizes shorelines, as the research area's interventions confirmed and demonstrated (Guannel et al., 2016). Its inherent resistance to extreme weather and sea level rise aids in climate change adaptation. Quantitative findings demonstrate cost-effectiveness, biodiversity growth, erosion control, wave attenuation, sediment trapping, and carbon sequestration in addition to coastline protection. Mangroves improve water quality by absorbing wave energy, supplying habitat for a variety of marine species, and filtering silt and contaminants. It also contributes to an increase in carbon sequestration per acre annually and species richness. These outcomes could, however, differ according on the mangrove species, location, and other variables. When compared to conventional coastal buildings, mangrove bio-fencing is 30–50% more cost-effective.

Figure 4: Comparative Chart (Coastal Erosion)



Kerala's coastline is dropping daily, according to reports on shoreline erosion rate from 2000 forward. The pace is rising yearly. The main cause of this is sea level variations brought on by climate change and global warming. However, as compared to other areas of the district and neighbouring districts, the study area's coastline erosion rate is noticeably under control, which is a promising and noteworthy development. It can be the outcome of bio-fencing, which is progressively enhancing the shoreline and the lives of the coastal populations. While sea level rising poses an increasing threat to coastline erosion along other seacoasts, the Chethy beach research region continues to experience normalcy. Tetrapode fencing and the typical seawall are expensive techniques that require ongoing upkeep. But the bio-fencing method is the most cost-effective, with the exception of the first sow period for saplings and watering for two to three months. The study area serves as an obvious illustration of this.

Major Findings

- The average sea level has risen by 8 to 9 inches (21 to 24 cm) since 1880. The main causes of rising sea levels include global warming and greenhouse gas emissions, which result in melting glaciers and ice sheets, as well as the thermal expansion of seawater as it warms.
- The west coast of India, which borders the Arabian Sea, continues to experience the severe impact of climate change and global warming as a result of rising human population and fossil fuel emissions. As a consequence, there has been an increase in temperature, erosion of the shoreline, algae blooms, ocean acidification, and fish migration. Coral bleaching is impacted by acidification, which also poses a threat to water resources close to the ocean.
- Since 1990, the frequency of super cyclonic storms has increased, and the ocean's temperature has risen due to a surplus of heat and energy.
- The 2004 tsunami and the Ockhi cyclone in 2017 both seriously destroyed Kerala's coastline, especially in the study region.
- Following the disastrous 2004 tsunami, the National Service Scheme unit at St. Michael's College in Cherthala proposed a bio-fencing strategy in the study area, which had been its adopted village since 2000.
- The study looked at the ways that local, state, and national governments, as well as the St. Michael's College National Service Scheme unit in Cherthala, manage coastline erosion and dangerous waves, which endanger the lives of fishermen and coastal dwellers.

- The declining number of fish, the disappearance of "Chakara," the extinction of fish species, the ban on trawling, the frequency of stomas and cyclones, and the threat of erosion and mighty waves to their habitat make life in the fishing community miserable.
- The study examines shoreline issues in Alappuzha, especially in the study area (Chethy beach) affecting 73% of fishermen community. Factors include coastal erosion, climate change, sand mining, rising ocean temperatures, and rising fish distribution. The Coastal Regulation Zone has led to migration, depreciation, flooding, and displacement, while monsoon turbulence causes loss and depression.
- The study investigates problems caused by climate change and global warming, such as coastline erosion, salt intrusion, and other emergencies, as well as man-made interventions such built-up regions and mineral extraction. 39.12% of Alappuzha's shoreline eroded between 1973 and 2021, with the south seeing the greatest rate of erosion.
- Kerala's coastal erosion rate averages 0.5-1.5 meters per year, with higher rates in Chethy (Alleppey) from 2000-2015, significantly higher than other seashores in Kerala.
- The study explores the effectiveness of mangrove and Casuarina Equisetifolia fencing as coastal defence against floods, sea surges, and erosion. St. Michael's College National Service Scheme planted mangrove saplings, protecting 0.9 km of shoreline and 1.7 km of Casuarina Equisetifolia bio-fence.
- Tetrapodes, traditional fences, struggled to prevent soil erosion along shorelines during the monsoon season due to sea conditions. TetraPOT, special pots, are now used to encourage root development and plant growth, forming natural mangroves.
- Mangrove bio-fencing is significant in avoiding soil erosion, tidal waves, and other marine calamities, and 30–50% more cost-effective than other measures when compared to conventional sea walls and coastal defences.

Conclusion

Mangrove bio-fencing improves coastal resilience, biodiversity, and stability by reducing wave energy and promoting climate change adaptation. It also enhances water quality, reduces erosion, and contributes to carbon sequestration. Compared to conventional coastal buildings, mangrove bio-fencing is 30-50% more cost-effective. *Chethy* beach research region is thriving amidst global warming and sea-level changes, thanks to cost-effective bio-fencing, which significantly improves coastal populations compared to traditional methods. However, the

suitability of mangrove species for Kerala's shoreline, the monitoring of erosion, the optimization of wave dynamics, and the assessment of socioeconomic advantages all require more investigation. Large-scale implementation, community involvement, integration with current structures, policy backing, frequent maintenance and monitoring, ecological restoration, and research-based design are among the recommendations. Kerala can efficiently use mangrove fencing to safeguard its shoreline and improve coastal resilience by filling in these gaps and putting these suggestions into practice.

References

- Causes and Effects of Climate Change | United Nations. (n.d.). United Nations. <https://www.un.org/en/climatechange/science/causes-effects-climate-change#:~:text=As%20greenhouse%20gas%20emissions%20blanket,the%20usual%20balance%20of%20nature.>
- Clark, J. R. (2018). Coastal Zone Management Handbook. In CRC Press eBooks. <https://doi.org/10.1201/9781315139654>
- Climate crisis may cause 14.5 million deaths by 2050. (n.d.). World Economic Forum. <https://www.weforum.org/press/2024/01/wef24-climate-crisis-health/#:~:text=New%20World%20Economic%20Forum%20analysis,life%20years%20lost%20by%202050.>
- Department of Fisheries. (2018). Records on Ockhi of Department of Fisheries, Thiruvananthapuram.
- Gotz Hoeppe. (2007). Conversations on the Beach: Fishermen's Knowledge, Metaphor and Environmental Change in South India. New York: Berghahn Books.
- Govt. of Kerala. (2005). Socio-Techno-Economic Survey of Fisherfolk in Kerala – 2004. Thiruvananthapuram, Kerala: Department of Fisheries.
- Govt. of Kerala. (2016). Socio-Economic Survey of Fisherfolk in Kerala – 2013. Thiruvananthapuram, Kerala: Department of Fisheries.
- Guannel, G., Arkema, K., Ruggiero, P., & Verutes, G. (2016). The Power of Three: Coral Reefs, Seagrasses and Mangroves Protect Coastal Regions and Increase Their Resilience. PLoS ONE, 11(7), e0158094. <https://doi.org/10.1371/journal.pone.0158094>
- Jennath, A. (2024, June 24). Caught between land and sea, Kerala's coastal communities weigh climate stress against livelihood. <https://thewire.in/environment.https://thewire.in/environment/caught-between-land-and-sea-keralas-coastal-communities-weigh-climate-stress-against-livelihood>
- Lindsey, R. (2022, April). Climate Change: Global Sea Level (R. Lumpkin, G. Johnson, P. Thompson, & W. Sweet, Eds.). <https://www.climate.gov/news-features.https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level#:~:text=Global%20mean%20sea%20level%20has,of%20seawater%20as%20it>

Manorajan Mishra, Namita Pattnaik, Manoj kumar Dash, DambaruBallab Kattel and Shailendra Kumar Mishra (2020) Analyzing trend of tropical cyclone activity along Odisha Coast, India. Research Square <https://doi.org/10.21203/rs.3.rs-30112/v1>

Rajan.J.B. (2019). Marunna Matsya Mekhala, Pranthavalkkarikkunna Matsya Thozhilalikal (Changing Fisheries, Marginalising Fishermen). Trissur, Kerala: Kerala Institute of Local Administration.

Simrin Sirur. (2024, May 10). Assessing coastal disaster risks in central Kerala. Mongabay-India. <https://india.mongabay.com/2024/05/assessing-coastal-disaster-risks-in-central-kerala>

Wilson, R. S., Herziger, A., Hamilton, M., & Brooks, J. S. (2020). From incremental to transformative adaptation in individual responses to climate-exacerbated hazards. *Nature Climate Change*, 10(3), 200-208.

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Dharma in the Digital Era: Integrating Vedic Philosophy with AI Ethics

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Abstract

The rapid growth of technology or artificial intelligence (AI) raises significant concerns about the morality and ethics of its invention and use. As AI continues to have an impact on our environment, it is important to combine timeless philosophical considerations with contemporary AI ethics. This research explores the intersection of Vedic philosophy with AI ethics, aiming to know how ancient Indian knowledge can deepen our knowledge of AI and its impact on society. The paper examines how Vedic concepts may provide a framework for AI ethics, which considers sustainability, societal responsibility and human well-being using the principles of religion, karma and non-violence. The study looks at how these concepts can be applied to the challenges of modern AI, which includes presumptions or prejudicial views, transparency and accountability. This research aims to contribute to a deeper comprehension and awareness of the role of AI within society by integrating Vedic philosophy with AI ethics.

Keywords: Vedic Philosophy, AI Ethics, Cultural Heritage, Ethical Framework, Viksit Bharat.

The use of AI has emerged as one of the greatest disruptive forces influencing human life in an era of fast technological advancement. AI has dominated practically every sphere of daily life, including banking and entertainment, to healthcare and education, offering unmatched efficiency, creativity, as well as growth. However, there are significant worries about the impact of this enhanced technological power on morale. International discussion has been sparked by issues of impartiality, transparency, and accountability, especially the ethical implications of AI-controlled decision-making. The demand for stricter ethics regulations grows as society deals with these problems.

Parallel to this evolution, the philosophy of the Vedas, Puranic consideration, and other Indian religious practices offer a timeless perspective concerning mortality, ethics, and the significant of human action. Vedic philosophy, rooted on the notion of “*dharma*” (justice, obligation, and universal order), offers a complete understanding about ethical conduct as well as the connection between individual choices and societal wellbeing.

Vedic philosophy is a system of concepts and practices rooted in the ancient Indian culture and centred on the Vedas. It serves as an essential component as well as is widely regarded as an important aspect of Indian philosophy. The doctrine of the Vedas focuses on the interconnection of all in existence, the notice regarding a universal consciousness known as “*Brahmaan*”, the soul that is unique or “*Atman*” inside each being or the significance of living righteously in accordance with Dharma (moral duty) while adhering the fundamental principle of Karma (cause alongside effect) in order to attain liberation (Moksha) coming from the vicious cycle of rebirth. It frequently emphasises the pursuit of learning and enlightenment via activities such as meditation and rituals.

Seeing Religion in Context

Religion is a broad concept that includes obligations, rights, laws, practices, virtues, and the moral order of the universe. It focuses on balance- the harmonious harmony of human activities and universal consciousness. Despite rigid legal frameworks, religion is fundamentally contextual and adaptive, recognising that situations, roles, and relationship influences ethical behaviour. For example, the Bhagavad Gita, the foundation of Vedic philosophy, exemplifies this transformative power through the language of Krishna and Arjun. Ithamar Theodore’s study of the Bhagavad Gita offers a modern, single approach to the ancient text, encompassing philosophical, theoretical, ethical and practical considerations. Including new translations,

different sections and in-depth commentaries, it makes the Gita accessible to a wider audience while emphasising its universal significance (Theodor, 2016).

This view of viewing religion in the context of AI ethics as ensuring that technological advances serve the greater good, preserve individual dignity, and promote social cohesion is the typical weak utilitarian strategy used AI design, which is the inverse of ethical. Profitability and efficiency are favoured in terms rather than religious intent, which emphasises long-term impact, inclusion, and the ethical responsibility of producers and users.

Ethical Issues Surrounding AI: A Religious Perspective

The article examines how artificial intelligence can transform religious practices through applications, social networks and online activities. It examines ethical concerns, authenticity and inclusion, providing a balance between setting important technological and spiritual values, and addressing the impact of AI on the development of faith and human relationships (Alkhouri, 2024). The ethical issues raised by AI are vast and complex. Issues such as algorithmic bias, confidentiality violations, business migration, and misuse of capable devices highlight the critical need for codes of ethics. Current policies, e.g. the EU AI Act and the UNESCO AI ethics theory, are useful starting points, but often historical and philosophical depths are absent. We can improve on this system by adopting Vedic ideas, especially religious ones for example:

- **Prejudice and Justice:** Religion values fairness and justice. This methodology for AI aims to create impartial algorithms that are fair for every consumer, irrespective of their ethnicity, gender, and socioeconomic background. This needs both technical solutions and ethical considerations.
- **Transparency along with accountability:** The essential concepts of Vedic philosophy involve truth(reality) and responsibility (karma). These concepts can aid in creating transparent AI system featuring accessible decision-making processes alongside clearly specified computational methods.
- **Sustainable development and wellness:** Religion encourages activities that benefit everyone while also maintaining natural equilibrium. AI ethics prioritize sustainability, environmental stewardship, for human well- being over short- term profit.
- **Liberty and dignity for human beings:** Individual freedom is implicitly valued throughout religious thought. AI systems should prioritise human decision-making to increase their productivity, instead of decreasing its productivity.

Combining Ancient Wisdom with Modern Ethics

While Vedic philosophy and its principles provide deep understanding, their integration into AI ethics demands careful contextualization as well. The digital age introduces new information that the prior system may not have predicted. The faith, on the other hand, is well suited for this sort of position due to its adaptability. By transferring traditional concepts or ideas into practical suggestions, we can tackle contemporary issues while remaining connected with these timeless ethical values by paying attention to these Vedic techniques, which can help AI developers in designing an ethically appropriate education curriculum, which allows them to reflect on the broader implications of their work. Research examines how the spiritual wisdom of ancient Indian literature could promote social inclusion along with justice. It investigates major principles such as “*Vasudevam Kutumbkam*” (universal connectedness) and “*Ramrajya*” (moral governance), emphasising their relevance to contemporary challenges such as equal opportunities for everyone and universal compassion, with the goal of creating a harmonious world. (Ravi, 2024).

The Way Forward

As AI advances, the need for transdisciplinary approaches towards ethics becomes more critical. This study contends that incorporating the wisdom of the Vedas into AI ethics is a suitable start towards meeting this demand. By using spiritual principles, we may create an integrated ethical framework that brings together technical advancement with human values

Researchers studied the use of AI for the preservation, analysis and understanding of ancient Sanskrit manuscripts. It also discusses how Sanskrit thought can influence the development of AI, emphasising the value of language learning, history studies, and technological development. (Salunke, et. al., 2024).

Ultimately, the goal is not to impose ancient traditions on a modern system, but to encourage a dialogue between them, harnessing their strengths to create a future where technology helps humanity, and follows ethical standards on the largest scales. This combination allows us to meet the obstacles of the digital age with intelligence, empathy and commitment to the good of humanity.

The central point of this study is the application of the principles of Dharma (righteousness), Karma (the law of action and consequence), Ahimsa (non-violence), Satyam (the truth), and Atman (eternal self or soul) towards forming a sound base for AI ethics. Vedic philosophy, in

this research, provides an old yet contemporary understanding of morality, responsibility, and interconnectedness of life. They can provide a promising answer to the ethical dilemmas raised by AI technologies, such as algorithmic transparency, accountability, and sustainability, through encouraging an inclusive sense of what it means to act responsibly in a globalised digital world.

Vedic philosophy is not just a written literature but also goes beyond that. It can be determined as a set of ideas and the ancient Indian thoughts based on and derived from the Vedas. It mainly focuses on concepts of the Universe, the Soul and Cosmic order. In Indian tradition and Culture, there are Four Vedas- *The Rigveda*, *The Yajurveda*, *The Samaveda* *The Atharvaveda*. These Vedas are considered the source of divine knowledge and provide a vast range of information. As the evolution occurs, the learnings of these Vedas were also found in Upanishads, the Bhagwat Gita, and many Shlokas. There should be no doubt the fact that these traditional learnings through these texts and literature can immensely revolutionise the human community if used correctly with AI technologies.

The significant growth of Artificial Intelligence and its role in modern society poses deep ethical challenges that require careful and ethical consideration from inter-disciplines to ensure the progress of technology and humanity.

At such a stage of the digital era, the involvement of old ethical values through Vedic philosophies and ancient records becomes much more important to guide the system and realm of AI ethics, which offers us a route to knowledge and leads growth of technology with religious wisdom. This is because blending the insights of Vedic thought with the development of AI technologies would allow us to pave the way for more ethically sound AI systems while promoting further awareness about the human experience within a digital age.

Nowadays, Technology has been integrated into our daily lives, affecting the youngest child in the community to the oldest (it could be smartphone usage, AI, and other electronic tools). If used properly and to the best extent, AI can play a major role in improving people and their lives to avoid a less efficient life, leading to a more productive life. However, the same thing that favours them can turn against them when used poorly or inappropriately. For instance, the children now have the best access to cell phones and the internet. Without any proper management on their part, this may send them to very bad content that is not suited for their vulnerable minds. Hence, ethical considerations should find a place in AI systems that take users to constructive and positive ends. Through the integration of principles from ancient

Vedic philosophies and texts, the designed AI would not be focused much on negative distractions but on personal growth, self-motivation, and mindfulness. This balance can lead the world positively, ethically and in a safe way.

Literature Review

The integration of Vedic philosophy with AI ethics is an exciting area of research that aims to investigate the relationship between ancient Indian wisdom and modern technology breakthroughs. This literature review will provide an overview of the current research in this field, emphasising significant concepts, themes, and disputes.

Ethical Foundations:

Vedic Philosophy

- Ethics examines the ethical dilemmas of individual-society relationships, affecting fields such as business and law. It incorporates ethical concepts into literature and thought in Indian culture, with classic poems such as the Ramayana and the Upanishads. It shows their role in value addition & culture change. (Tyagi, Isser 2024).
- The 21st century requires capabilities such as communication, creativity, productivity, teamwork and critical thinking in line with traditional views. According to Hinduism, 21st century philosophy is based on logical and critical thinking. Consequently, Vedic energies must find a proper place and urge mankind to live well in this century. (Untara, et. al., 2024).

Artificial Intelligence

- A study which was done to understand AI reveals two major shortcomings. First, the program lacks field testing, further research is needed to test its effectiveness in schools with special needs institutions second, it ignores teacher competencies in teaching AI, and emphasizes the importance of studying AI training processes & their impact on studying design. (Chiu, et. al., 2024).
- Neuroscience has an importance role to play in improving AI. But a closer look reveals that, while AI originates because of the shape of the brain, most of the focus has shifted from AI to neuroscience, which has changed what we know about how the brain works and its activity. (Gershman, 2024).

Practical Integration:**Vedic Philosophy**

- Researchers examine the relationship between Vedic philosophy and psychology in school. It is an analysis of ancient Vedic literature, such as the Vedas and the Upanishads and teaches important psychological principles such as mindfulness and self-reflection. The study examines their impact on student interest in academic achievement and provides information on its practical application in today's educational setting. (Jangamkote Kiran, Bharadwaj, 2024).
- A study examines the global impact of Vedic Sanatan Hinduism outside of India, including meditation and rituals including religion. It explores the contributions of literature, science and government, which concludes that the Vedic traditional has influenced global civilization and remains relevant, and provides an international framework for a cohesive human society. (Brahmacari, 2024).

Artificial Intelligence

- A study review discusses the benefits of using artificial intelligence in clinical practice, including data analysis, diagnosis, and personalised medicine. It explores the use of AI in medicine, ethical considerations such as confidentiality and open disclosure, and the need for careful development to ensure constitutional and ethical compliance. (Karalis, 2024).
- A study explores how AI can improve energy & resources consumption, with a focus on increasing green energy consumption. Analysing data collected by 100 energy providers, they found that AI could increase energy efficiency by 25%, improve sustainability and reduce emission impacting our environment, thereby contributing to global sustainable energy initiatives. (Audiah, et. al., 2024).

Cultural Relevance:**Vedic Philosophy**

- A paper examines the philosophical determinants of the Indian Knowledge System (IKS) and its relevance to contemporary concerns such as environmental degradation, mental health and caste division. It examines key tradition such as Vedanta, Nyaya and Sankhya, and promotes IKS as a model

of ecologically sustainable development and understanding of multiculturalism. (Nath, 2024).

- One paper also examines the relevance of the values of the Bhagavad Gita to modern society. Regarded as the jewel of Indian spiritual wisdom, the Gita contains moral ideas that affect personality, culture and everyday life. It examines how these values, whether based on religion or community, remain relevant for the next generation.

Artificial Intelligence

- A study looks at the influence of socio-cultural factors on middle school students' perceptions of machine learning (AI). It finds that experiences with gender IQ influence student behaviour in different ways, and that AI education enhances behaviour, especially for those facing social and cultural challenges. Interest in both AI & programming experience greatly improves perception of AI. (Kim, Lee, 2024).
- A paper presents a model for integrating cultural perspectives into artificial intelligence using a cultural model based on the self-environment. Two studies show that background culture influences optimal AI preferences, with Chinese respondents endorsing transcendental communication and African American participants exhibiting a mixture of European American and Chinese perspectives. The study builds emphasizing the importance of culturally respective AI. (Ge, et. al., 2024).

Challenges faced

Vedic Philosophy

- Current challenges include rapid technological development, environmental disasters and social unrest. Addressing these issues requires an Indian philosophical outlook, especially the Vedic scriptures of the Upanishads, which emphasis communication, ethical responsibility and ecological balance with environment it emphasizes balance in responses to sustainable living, global peace and moral governance (Chauhan, 2024).
- Nirmalyanarayana Chakraborty's research examines ethical issues in the Mahabharata, including law- abiding and ethical paradoxes he examines, and discusses, Yudhishtir's moral conflicts of infidelity and self- deception against

universal morality. Bhishma's perspective emphasises religious dilemmas and argues that moral reasoning derives from social customs rather than external values (Chakraborty, 2024).

Artificial Intelligence

- A study examines the AI TRISM framework, which ensures the reliability of AI in areas such as smart cities or healthcare. It discusses AI TRISM applications, challenges & adversary threats such as regulatory compliances, and future prospects, with a focus on transformation and collaboration towards ethical AI safety (Habbal, et. al., 2024).
- Challenges in implementing AI in education include tackling literacy gap, business integration and costs, readiness in organisational characteristics, technical issues such as data bias and privacy, and ethical concerns about confidentiality. (Ali, et. al., 2024).

Future Outlook

Vedic Philosophy

- The legacy of Vedic teachings in Indonesia has cultural and spiritual significance, and provides moral guidance and welfare benefits. Despite the limitations of globalisation and modernity, ongoing conservation efforts keep it alive. Future plans include integrating Vedic teaching into public school to promote global consciousness and cultural heritage (Seriadi, 2024).
- A research report shows how changing corporate environments and social pressures can lead to increased stress, morale and unemployment. It emphasises the critical importance of a pleasant work environment and delves into practices from Hindu texts that can help individuals and companies to manage stress and tension (Srivastava, et. al., 2024).

Artificial Intelligence

- A research article examines the application of AI in education, namely language learning. It highlights AI's ability to personalize and improve learning by providing opportunities for feedback & action. The study highlights the role of AI in improving the teachings of today's educational models and transforming pedagogical approaches (Nurjanah, et. al., 2024).

- An article examines the impact of ChatGPT on education, including its ability to create content, support teachers, and encourage teamwork. It also addresses issues such as errors, plagiarism, and “strange design”. The study focuses on changes in learning style and emphasizes educating teachers and students on the capabilities and limitation of ChatGPT (Gill, et. al., 2024).

Research Methodology

Research Type	Exploratory
Sampling Technique	Random Sampling
Sample Unit	People from Jaipur
Sample Size	105
Tools for data collection	Questionnaire based on Scale of 5 Likert points (Strongly agree= 5, Agree= 4, Neutral= 3, Disagree= 2, and Strongly Disagree= 1)
Tools for data analysis	Frequency Distribution, Percentage, Mean and Standard Deviation. • The data was analyzed with the help of random sampling through the google form.

Objectives of the Study

- To Spread awareness and the hidden strength of Vedic Philosophy Globally.
- To help people understand the concept of Dharma (Righteousness), Karma (Action and Consequences), Self or Soul taking AI as a medium to promote responsible and harmonious technological advancement.
- To enhance AI- Human interaction by interconnecting all aspects and emphasize Self- awareness and promote personal growth.

Data Analysis & Findings

(Strongly agree= 5, Agree= 4, Neutral= 3, Disagree= 2, and Strongly Disagree= 1)

Sr. no.	Questions	5	4	3	2	1
1.	Integration of Vedic Concepts into AI Ethics:					
	AI system should incorporate ancient wisdom like Vedic concepts to enhance fairness and accountability.	28	57	19	1	0
	In modern technology, it is possible and feasible to integrate Vedic concepts with AI ethics.	22	61	18	4	0

	AI developers should learn traditional ethical framework like Vedic concepts to avoid misuse.	26	57	17	3	2
	Older ethical principles like Vedic concepts should be considered in future AI legislation.	32	57	13	3	0
2.	Universality and Acceptance of Vedic Concepts in AI:					
	Vedic concepts in AI can be universal and accepted by everyone.	27	47	25	5	1
	AI ethics must take into account multiple cultural and intellectual traditions.	26	59	17	1	2
	Vedic education can improve global moral intelligence while avoiding cultural biases.	33	45	23	3	1
3.	Ethical Alignment with Modern AI Concerns:					
	Vedic concepts can help AI make better moral decisions	28	46	26	3	2
	Basic Vedic ethical principles (such as dharma and karma) match today's AI ethics.	16	43	28	14	4
	AI development should balance new technology with old wisdom.	31	56	17	0	1
4.	Challenges in Applying Vedic concepts to AI:					
	Integrating Vedic concepts into AI ethics can lead to religious biasness.	16	47	30	11	1
	Tech experts may oppose the introduction of Vedic concepts in AI development.	16	51	30	7	1
	More knowledge and education are needed to effectively integrate Vedic concepts into AI system.	30	56	17	2	0

Source: Primary Data

Interpretation

This investigation investigates the perspective on applying Vedic concepts into the ethical framework of artificial intelligence. The data came out to be slightly favorable for the idea, but it highlights important issues and factors that must be better explored.

Positive Attitudes Toward Integrating Vedic Concepts

The majority of respondents believe or strongly believe that Vedic wisdom should be infused into AI ethics in order to achieve fairness and accountability. For example, 81% of

respondents (28+57) strongly agreed or partially agreed that artificial intelligence devices should incorporate old wisdom, such as Vedic principles. Similarly, 80% believe that Vedic ideals may be included in AI ethics using modern technology. Furthermore, there is a broad consensus (80%) believe AI developers should grasp ancient frameworks such as Vedic ideas to prevent misuse, indicating a belief on the practical importance of this approach. An impressive 85% of respondents agree that ancient ethical ideas, such as Vedic ideals, should be addressed in future Intelligence legislation, indicating a desire to officially codify this integration.

Universality and Acceptance of Vedic Concepts

The survey found that Vedic notions are widely accepted and universally applicable in AI. A combined 70% of respondents believe that Vedic notions in AI may be broadly accepted. There is also widespread agreement (81%) that AI ethics should take into account numerous cultural and intellectual traditions, indicating an openness to different ethical contributions. 75% of respondents agree that Vedic education can boost global moral intelligence while avoiding cultural bias. This demonstrates trust in the possibility of Vedic concepts making a beneficial difference to global ethical conversation in AI.

Alignment to Modern AI Concerns

Data suggest that Vedic principles can help address ethical issues in modern AI. A total of 71% of respondents believe that Vedic ideals can help AI create better moral decisions. However, there is less agreement (56%) when it comes to key Vedic ethical principles such as Dharma and Karma mirroring modern AI ethics, with a sizeable fraction (26%) staying neutral. However, an overwhelming majority of 83% believe that the growth of AI should be blended with technological advances and old wisdom, indicating a desire for an appropriate combination of tradition and innovation.

Obstacles and Concerns

While the general attitude is optimistic, the study identifies some obstacles. One major problem is prejudice based on religion (60% agree). There is also an obvious reluctance among technocrats to include Vedic notions into the creation of artificial intelligence, with 64% believing that this could prove difficult. However, the most significant problem noted is the need for additional understanding and education when incorporating Vedic notions into

artificial intelligence, with an overwhelming 82% agreeing on this point. This is to focus on research and learning that can overcome the Vedic wisdom difference using AI technology.

Interpretation and Implications

The survey results indicate a promising opportunity to incorporate Vedic themes into AI ethics. The significant agreement on the importance and feasibility of incorporating implies a willingness among the questioned population to pursue this option further. However, the observed problems are linked to potential biases, yet a demand for more education emphasises the significance of taking a prudent and nuanced approach.

Moving forward, religious bias allegations will be addressed with open dialogue and explicit frameworks. Tech specialists could be approached through seminars and collaborative initiatives to help overcome opposition. To effectively integrate oneself, one must invest in training courses and research projects that investigate the practical use of Vedic notions in AI ethics. This includes creating resources that convey Vedic concepts in a straightforward and understandable way for developers of AI and policymakers.

Overall, this study provides valuable insights into the possibilities and limitations of integrating Vedic themes into AI ethics. Recognizing and addressing these issues proactively will pave the way for a more ethically aware, culturally sensitive strategy for AI development, which draws on old traditions. To create an AI future that is both useful and responsible, researchers, educators, officials, and innovators in technology must work together.

Suggestions

- The Vedic texts provide a deep insight into most aspects of life, but the emphasis here is on individual discrimination and self-reflection. Hence, a person should analyse the situation and act upon it.
- Since Artificial Intelligence is a growing Technology, there is always a possibility that the user won't be able to find the context he/she is looking for. To avoid this, the system should be designed in such a way so that it can provide Deep Insights of Philosophy, Enhanced study of Consciousness and comparative synthesis of information.
- This idea can only be successful when the system is integrated to provide knowledge without diminishing other religious beliefs.
- The Vedas speak of ageless truths applicable across generations. While technology and its forms come and go in the human experience, it is this quality of the revelations of the Vedas that applies across all timelines. Developers who approach AI under the premise of knowing that as technology evolves, so does everything under it, except,

perhaps, its core principles with respect to life, ethics, or consciousness, would place AI where these timeless principles rest.

- AI and Vedic Philosophy should be integrated in such a way that they promote self-reflection and personal growth.
- People should understand that our Vedic philosophy, cultures and texts are very important and valuable to ourselves as well as upcoming generations. To ensure that the positive impacts of these literatures remain in our lives, People themselves need to take initiatives to save and spread the awareness in upcoming generations.
- Artificial Intelligence experts need to first learn and understand to importance of ancient and Vedic philosophy and culture and accordingly design the interface of various software through which people can easily interact with Factual and Holistic information.
- In the process of integrating artificial intelligence and Vedic philosophy, the framework should be ethical and full of consciousness, and the developers and makers should understand the concepts of *Dharma*, *Karma*, *Satya*, *Ahimsa*, *Atma* and should build the system in order to provide service for humanity.

Conclusion

In conclusion, the incorporation of Vedic philosophy into AI ethics shows great promise for confronting the ethical dilemmas or challenges generated by AI technologies. Applying the concepts of Dharma, Karma, and Ahimsa can be very useful in designing AI that is fair, transparent, accountable, and sustainable. Vedic philosophy, therefore, provides deep ethical structures by promoting the development of AI systems in full service to the greater good, human dignity, and social responsibility. Thus, there is an ever-greater urgency of building and developing a system which is holistic, inclusive, and has a compassionate approach towards AI development as its innovations evolve over time. By combining the wisdom these ancient traditions hold with the modern technological advancements, we can create a system which will primarily focus on humanity and harmonious living and form a sustainable world.

References

- Tyagi, P., & Isser, S. S. (2024). ETHICS AND VALUES IN INDIAN PHILOSOPHY. *International Research Journal of Humanities and Interdisciplinary Studies Volume 5, Issue 4, April 2024* <https://doi-ds.org/doi/10.2424-82835238/IRJHIS2404050>
- Untara, I. M. G. S., Sumaryani, N. M., & Surpi, N. K. (2024). The Vedic concept of work ethic and its relevance to 21st century competencies. *Dharmakirti: International Journal of Religion, Mind and Science, 1*(2), 50-62. <https://doi.org/10.61511/ijroms.v1i2.2024.610>
- Chiu, T. K., Ahmad, Z., Ismailov, M., & Sanusi, I. T. (2024). What are artificial intelligence literacy and competency? A comprehensive framework to support them. *Computers and Education Open, 6*, 100171. <https://doi.org/10.1016/j.caeo.2024.100171>
- Gershman, S. J. (2024). What have we learned about artificial intelligence from studying the brain?. *Biological Cybernetics, 1-5*. <https://doi.org/10.1007/s00422-024-00983-2>
- Jangamkote Kiran, V., & Bharadwaj, D. A. (2024). The Modern application of Vedic Wisdom and influence of Mindfulness on Education. *Amulya, The Modern application of Vedic Wisdom and influence of Mindfulness on Education (June 25, 2024)*. <http://dx.doi.org/10.2139/ssrn.4922682>
- Brahmacari, Dr. Srivas Krishna Das, Evidence of Vedic Sanātana Hinduism as a Global Dharma (September 19, 2024). *International Journal of Science and Research Archive, volume 13, issue 2, 2024*. <http://dx.doi.org/10.30574/ijsra.2024.13.2.2179>
- Karalis, V. D. (2024). The integration of artificial intelligence into clinical practice. *Applied Biosciences, 3*(1), 14-44. Karalis, V. D. (2024). <https://doi.org/10.3390/applbiosci3010002>
- Audiah, S., Sanjaya, Y. P. A., Daeli, O. P., & Johnson, M. (2024). Transforming energy and resource management with ai: From theory to sustainable practice. *International Transactions on Artificial Intelligence, 2*(2), 158-163. <https://doi.org/10.33050/italic.v2i2.554>
- Nath, S. (2024). Bridging the Past and Present: Philosophical Insights from the Indian Knowledge System. *BIJMRD Volume 2 Issue 9 October 2024* <https://doi.org/10.70798/Bijmrd/02090007>
- Bini, T. V. (2023). RELEVANCE OF VALUES ENSHRINED IN BHAGAVAD GITA IN THE MODERN SOCIETY. *Interdisciplinary e-Journal of Education and Allied Subjects Volume 4, Issue 2 – December 2023*

Kim, S. W., & Lee, Y. (2024). Investigation into the influence of socio-cultural factors on attitudes toward artificial intelligence. *Education and Information Technologies*, 29(8), 9907-9935. <https://doi.org/10.1007/s10639-023-12172-y>

Ge, X., Xu, C., Misaki, D., Markus, H. R., & Tsai, J. L. (2024, May). How Culture Shapes What People Want From AI. In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (pp. 1-15). <https://doi.org/10.1145/3613904.3642660>

Chauhan, S. S. K. (2024). ESSENTIALITY OF UNDERSTANDING AND FOLLOWING AN INDIAN PHILOSOPHY FOR THE UNIVERSE IN PRESENT TIMES. *ShodhShreejan: Journal of Creative Research Insights*, 1(1), 11-17. <https://doi.org/10.29121/shodhshreejan.v1.i1.2024.5>

Chakraborty, N. N. (2024). The Challenge to being Virtuous: A Lesson from the Mahābhārata. In *Traditional Indian Virtue Ethics for Today: An East-West Dialogue* (pp. 273-292). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-47972-4_15

Habbal, A., Ali, M. K., & Abuzaraida, M. A. (2024). Artificial Intelligence Trust, risk and security management (AI trism): Frameworks, applications, challenges and future research directions. *Expert Systems with Applications*, 240, 122442. <https://doi.org/10.1016/j.eswa.2023.122442>

Ali, O., Murray, P. A., Momin, M., Dwivedi, Y. K., & Malik, T. (2024). The effects of artificial intelligence applications in educational settings: Challenges and strategies. *Technological Forecasting and Social Change*, 199, 123076. <https://doi.org/10.1016/j.techfore.2023.123076>

Seriadi, S. L. N. (2024). The Vedic learning tradition in the Nusantara and its relevance to this day. *International Journal on Hindu Culture*, 2(01), 93-103.

Srivastava, S. K., Agnihotri, K., & Gupta, O. (2024). Management of class-room stress with the help of Vedic teaching philosophy. *International Journal of Internet Manufacturing and Services*, 10(1), 47-59. <https://doi.org/10.1504/IJIMS.2024.136712>

Nurjanah, A., Salsabila, I. N., Azzahra, A., Rahayu, R., & Marlina, N. (2024). Artificial intelligence (ai) usage in today's teaching and learning process: A review. *Syntax Idea*, 6(3), 1517-1523. <https://doi.org/10.46799/syntax-idea.v6i3.3126>

Gill, S. S., Xu, M., Patros, P., Wu, H., Kaur, R., Kaur, K., ... & Buyya, R. (2024). Transformative effects of ChatGPT on modern education: Emerging Era of AI

Chatbots. *Internet of Things and Cyber-Physical Systems*, 4, 19-23.

<https://doi.org/10.1016/j.iotcps.2023.06.002>

Theodor, I. (2016). Exploring the Bhagavad Gita: Philosophy, structure and meaning. Routledge. *Routledge 1st Edition* <https://doi.org/10.4324/9781315581712>

Alkhouri, K. I. (2024). The role of artificial intelligence in the study of the psychology of religion. *Religions*, 15(3), 290. <https://doi.org/10.3390/rel15030290>

Ravi, M. P. (2024). FORGING INCLUSIVITY, PEACE, AND JUSTICE: THE ROLE OF DHARMIC WISDOM IN MODERN SOCIETY. *Svādhyāya - International Journal of Transdisciplinary Research and Development (SIJTRD) ISSN Online: 2583-1739 Vol 3(2), March 2024, order, 3(2), 72-78.*

Salunke, L. S., Vengurlekar, V. S., & Gurav, M. P. (2024). BRIDGING ANCIENT WISDOM AND MODERN TECHNOLOGY: SANSKRIT AND AI. *INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREAMS) Vol. 04, Issue 05, May 2024.* <https://www.doi.org/10.58257/IJPREAMS34557>

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Impact of Extreme Weather Events on the Outbreak of Disease

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Abstract

Extreme weather events, driven by climate change, are emerging as a critical determinant of global health. Rising greenhouse gas emissions, disruptions in the Pacific Ocean's climate-regulating mechanisms, and phenomena like La Niña have caused significant disturbances in the water cycle, agriculture, and regional climates. In India, erratic monsoons and increased evaporation exacerbate agricultural and water crises, while countries like Indonesia face flooding and soil erosion, with projections of severe land loss by 2040. Meanwhile, South America experiences intensified droughts, creating hotspots of ecological imbalance. Such changes foster disease outbreaks by providing ideal conditions for pathogens and vectors. Dengue fever thrives in warmer, wetter environments, as evidenced by its rampant spread in Bangladesh and the emergence of Asian tiger mosquitoes across Europe. Drought-induced malnutrition and flooding-related contamination have amplified diseases such as diarrhoea, Zika, chikungunya, and leptospirosis. This paper explores the complex biological mechanisms by which climate change fosters disease proliferation, emphasising vector ecology, microbial growth, and immune responses. With evidence-backed insights, it underscores the urgency for integrated global strategies to mitigate climate-induced health crises.

Keywords: Climate change, Extreme weather events, Disease outbreaks, Vector ecology, La Niña, Public health.

Epidemics are like signposts from which the statesman of stature can read that a disturbance has occurred in the development of his nation – that not even careless politics can overlook.

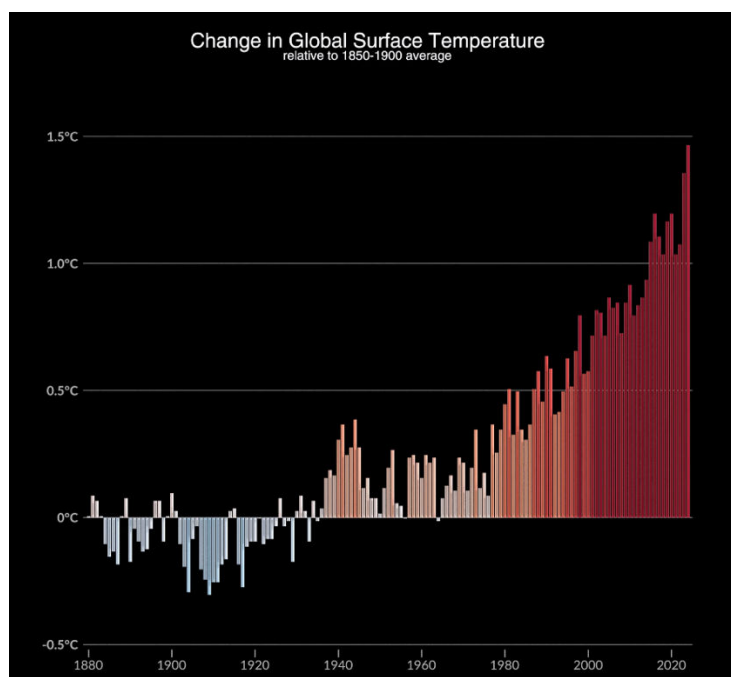
– **Dr Rudolf Virchow, 1848**

Climate change has become one of the defining challenges of the 21st century, significantly altering ecosystems, human livelihoods, and global health. Among its most alarming consequences are extreme weather events—heatwaves, cyclones, droughts, and floods—that are increasingly frequent and severe. These events disturb the delicate balance of the Earth's systems, influencing disease patterns and exacerbating health crises worldwide.

Causes of Extreme Weather Events

Climate Change as the Driver The intensification of extreme weather events is primarily linked to anthropogenic climate change. Rising levels of greenhouse gases such as carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) trap heat in the atmosphere, resulting in global warming. This warming disrupts atmospheric circulation patterns, ocean currents, and weather systems.

A visualisation of global temperature anomalies highlighting the record years of 2024, 2023, and 2016. The visualisations morph between a data grid showing monthly temperatures and a bar chart of annual temperatures.



Data Source: NASA's Scientific Visualisation Studio –by Visualizer: Mark SubbaRao (NASA/GSFC)

The Role of the Pacific Ocean The Pacific Ocean plays a pivotal role in regulating global climate. Phenomena like El Niño and La Niña, driven by sea surface temperature anomalies, significantly influence weather patterns. The ongoing “triple-dip” La Niña event (2020–2024) has caused pronounced cooling in the Pacific, leading to erratic rainfall in South Asia and severe droughts in South America.

Disturbances in the Indian Monsoon The Indian monsoon, vital for agriculture and water security, is increasingly erratic. Enhanced evaporation due to rising temperatures results in intense but uneven precipitation. Northern India experiences flooding, while regions like central India face drought-like conditions, amplifying vulnerabilities in agriculture and water management.

Global Water Cycle Disruptions Climate change accelerates the hydrological cycle, causing extreme rainfall in regions like Indonesia, Malaysia, and India, while intensifying droughts in South America. The resultant soil erosion, desertification, and groundwater depletion exacerbate regional inequalities.

Impacts on Human Health

Disease Outbreaks Due to Warmer Temperatures Warmer temperatures enhance the life cycle of disease vectors, such as mosquitoes, and provide ideal conditions for pathogens to thrive. Diseases like malaria, dengue, chikungunya, and Zika virus are becoming more prevalent in tropical and temperate regions alike.

Case Study: Dengue Fever in Bangladesh Bangladesh’s heavy rainfall and rising temperatures have created a perfect storm for *Aedes aegypti* mosquitoes, the primary vector for dengue. These conditions shorten mosquito breeding cycles and prolong their lifespan, leading to a dramatic increase in dengue cases. A table summarising reported dengue cases and mortality rates in various countries for the year 2023.

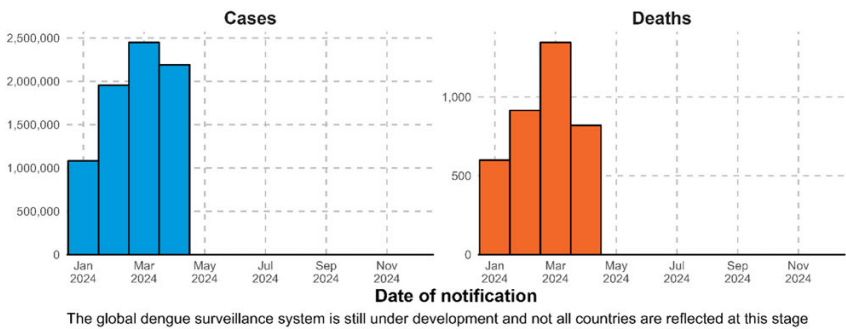
Table 1: Recent Dengue Outbreaks in Selected Countries (2023)

Country	Reported Cases	Mortality Rate (%)
Bangladesh	135,000	1.2
Brazil	2,300,000	0.3
Burkina Faso	15,000	2.5

Country	Reported Cases	Mortality Rate (%)
Fiji	8,000	0.5

Source: The World Health Organisation (WHO) provides comprehensive data on dengue outbreaks worldwide.

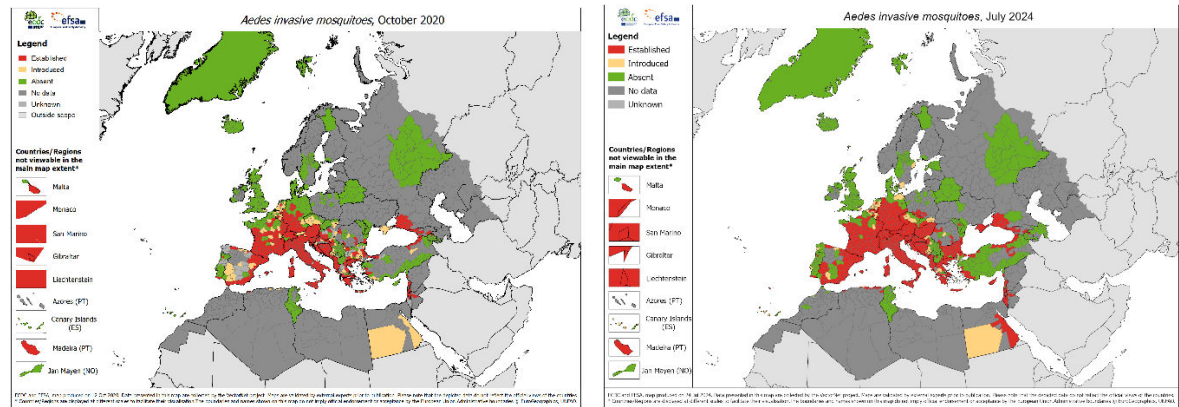
Figure 2: Epidemic curve of dengue cases and deaths as reported to WHO from January to April 2024*



Vector-Borne Diseases in Europe: The Asian tiger mosquito (*Aedes albopictus*), once restricted to tropical regions, has now established populations in most European Union countries. This mosquito is a vector for dengue, chikungunya, and Zika virus. Rising temperatures and urbanisation facilitate its spread, making insecticide use a public health necessity in Europe.

Figure 3: Geographic Spread of Aedes Mosquitoes in Europe (2010 vs. 2024)

A comparative map showcasing the expansion of *Aedes* mosquitoes, vectors for dengue and chikungunya, across Europe over the past decade.



Data Source: The European Centre for Disease Prevention and Control (ECDC) offers up-to-date maps on the distribution of invasive mosquito species in Europe.

Waterborne Diseases from Flooding: Floods, caused by intense rainfall, lead to water contamination with pathogens like *Vibrio cholerae*, *Escherichia coli*, and *Cryptosporidium*. This results in outbreaks of diarrhoea, cholera, and leptospirosis, particularly in low-income regions with inadequate sanitation infrastructure.

Malnutrition from Droughts: Droughts disrupt food production, leading to undernutrition and weakened immune systems. Malnourished populations are more susceptible to infectious diseases like tuberculosis and pneumonia, compounding public health crises.

Biological Mechanisms of Disease Proliferation

Vector Ecology: Climate change alters vector ecology by expanding the geographic range of mosquitoes, ticks, and flies. Higher temperatures accelerate their development, while increased rainfall creates breeding grounds in stagnant water.

Microbial Growth and Resistance: Rising temperatures enhance the growth rates of bacteria, viruses, and fungi. Warmer waters, for example, foster *Vibrio cholerae* proliferation, increasing cholera outbreaks. Simultaneously, extreme weather stresses healthcare systems, promoting antimicrobial resistance due to suboptimal treatment.

Human Immune Responses: Extreme weather events weaken human immune responses. Heat stress reduces the efficacy of immune cells, while malnutrition, caused by droughts, undermines the body's ability to fight infections. Flood-related trauma also increases susceptibility to infectious diseases.

Regional Case Studies

Table 2: Projected Health Impacts of Climate Change (2030–2050)

Description: A table outlining the anticipated additional deaths per year due to various health outcomes influenced by climate change.

Health Outcome	Additional Deaths per Year
Undernutrition	95,000
Malaria	60,000
Diarrheal Diseases	48,000
Heat Stress	38,000

Source: The World Health Organization (WHO) has published projections on health impacts related to climate change.

South Asia: Countries like India and Bangladesh face dual challenges of flooding and heat waves. Dengue, malaria, and cholera outbreaks are rising due to favourable conditions for vectors and pathogens.

Sub-Saharan Africa: Prolonged droughts in sub-Saharan Africa have increased undernutrition and water scarcity. This has led to higher incidences of respiratory infections, diarrheal diseases, and vector-borne diseases.

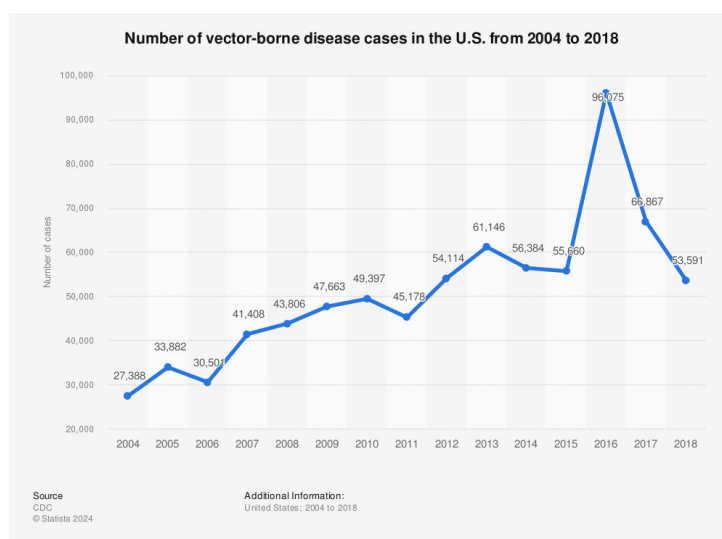
South America: Drought-induced wildfires in South America, particularly in the Amazon, have exacerbated respiratory diseases like asthma and bronchitis. The loss of biodiversity also reduces natural barriers to disease spread.

Europe and North America: Warmer climates in temperate regions have led to the northward expansion of vector-borne diseases. Lyme disease, spread by ticks, is now a growing concern in the United States and Canada.

Figure 4: Increase in Vector-Borne Diseases in the United States (2003–2023)

A line graph showing the rise in reported cases of vector-borne diseases, such as Lyme disease and West Nile virus, over the past two decades.

This graph shows the total number of vector-borne disease cases in the U.S. from 2004 to 2018. In the year 2004, there were 27,388 cases of vector-borne disease, while in 2018 there were 53,591 such cases.



Data Source: Statista 2024

Mitigation Strategies

Strengthening Public Health Systems: Investments in healthcare infrastructure, particularly in vulnerable regions, are essential to prevent and manage disease outbreaks. Early warning systems and vector control programs are critical components.

Climate Adaptation Policies: Adaptive measures, such as improving water management and sustainable agriculture practices, can mitigate the health impacts of extreme weather events. Reforestation and soil conservation can reduce erosion and desertification.

Global Collaboration: Addressing the health impacts of climate change requires coordinated global efforts. The World Health Organisation's Climate and Health Program is an example of an initiative aimed at integrating climate resilience into health policies.

Conclusion

The intersection of climate change and public health presents unprecedented challenges. Extreme weather events disrupt ecosystems and create conditions conducive to disease outbreaks, disproportionately affecting vulnerable populations. Comprehensive, interdisciplinary approaches are needed to mitigate these impacts and build resilient communities.

References

Intergovernmental Panel on Climate Change (IPCC) Reports.

World Health Organization (WHO) Climate and Health Program.

Peer-reviewed articles on vector-borne diseases and climate change impacts.

Regional health statistics from Bangladesh, India, and the European Union.

<https://doi.org/10.32776/revbiomed.v13i4.329> - Megadrought and mega-death in Mexico in the 16th century - *Rodolfo Acuna-Soto, David W Stahle, Malcolm K Cleaveland, Matthew D Therrell*

<https://doi.org/10.1093/epirev/mxi004> - Global Health Impacts of Floods: Epidemiologic Evidence - Mike Ahern¹ , R. Sari Kovats¹ , Paul Wilkinson¹ , Roger Few² , and Franziska Matthies³

Book - *Aedes aegypti: The Yellow Fever Mosquito* – Publisher: University Press Author: Samuel Rickard Christophers

Is Global Warming Harmful to Health? - BY [PAUL R. EPSTEIN](#) - Scientific American Magazine Vol. 283 No. 2 (August 2000)

[https://doi.org/10.1016/S1286-4579\(01\)01429-0](https://doi.org/10.1016/S1286-4579(01)01429-0) - Climate change and emerging infectious diseases Paul R. Epstein*

El Niño and health - [https://doi.org/10.1016/S0140-6736\(03\)14695-8](https://doi.org/10.1016/S0140-6736(03)14695-8) - R Sari Kovats, MSc sari.kovats@lshtm.ac.uk · Menno

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Climate change and infectious diseases J. A. Patz,¹ A. K. Githeko,² J. P. McCarty,³ S. Hussein,¹ U. Confalonieri,⁴ N. de Wet

[https://doi.org/10.1016/S1473-3099\(09\)70104-5](https://doi.org/10.1016/S1473-3099(09)70104-5) - Climate change and infectious diseases in Europe- Prof Jan C Semenza, PhD MPH jan.semenza@ecdc.europa.eu · Bettina Menne, MD^b

<https://doi.org/10.1016/j.envint.2015.09.007> - Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. Author -Xiaoxu Wu , Yongmei Lu , Sen Zhou , Lifan Chen , Bing Xu

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