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Harnessing Geospatial Technology for Sustainable Agricultural Development

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Abstract

Purpose of the Study: This empirical research analyzes the position of Geospatial Technology in Agriculture (GTA) and its relevance to precision farming, resource optimization, and sustainable agriculture. The study aims at testing the magnitude to which GTA improves decision-making, boosts productivity, and reduces farming problems. Further, the study measures the farmer's willingness to embrace geospatial innovations under changing technological scenarios.

Significance of the Study: This study adds to the existing literature on digital transformation in agriculture through the empirical findings on the efficacy of geospatial tools. The results provide policymakers, agronomists, and technology developers with useful information for the promotion of sustainable agriculture. Through the determination of the determinants of GTA adoption, the research assists in the development of strategies to enhance agricultural efficiency, environmental sustainability, and food security. The findings will also act as a guide to future research in precision agriculture and geospatial analysis.

Research Methodology: A mixed-methods research design is used, integrating survey data analysis and case studies to analyze GTA adoption and impact. The research uses SmartPLS for SEM to test hypothesized hypotheses to ensure statistical integrity. Public awareness and adoption patterns are explored to present a detailed picture of the impact of geospatial technologies on agricultural decision-making.

Underpinning Theory: The Diffusion of Innovation (DOI) theory serves as the theoretical basis for this research, which describes how agricultural stakeholders view and adopt Geospatial Technology in Agriculture (GTA). The framework provides a systematic way of analyzing adoption obstacles, perceived advantages, and the influence of external factors in the diffusion of geospatial technology. The

research also discusses methods to hasten adoption and optimize the positive effects of geospatial innovations on agriculture.

1. Introduction

The agricultural sector is undergoing much pressure from climate change, resource scarcity and should increase food production. GIS, remote sensing, GPS are some of the geospatial technologies which provides powerful means of monitoring, managing and optimization of agricultural practices. All these are watched in precision agriculture, which is the use of spatial data to enhance efficiency, productivity and sustainability.(Amato et al., 2022) With a detailed insight to soil health, crops conditions, water use, and other environmental factor, farmers are able to make informed decisions thereby maximizing crop yields while minimizing environmental impacts (Candiago et al., 2022).

However, integration of such technologies is not easy, particularly in developing countries with limited resources as well as technology know how. The focus of this paper is to examine geospatial technologies' chances to support the promotion of sustainable agricultural practices as opposed to their greater use. (EOS Data Analytics, 2022)

Motivation and Significance:

The core of the global food security, economic soundness, inclusiveness and sustainable development is agriculture. Nevertheless, many of the agricultural sector are being faced with enormous amounts of stress in order to cope with climate change, natural resource depletion, an unpredictable weather pattern, and an increased food demand arising from population growth. Solution that will address these challenges is advanced technological solution that allows increased productivity in agriculture without compromising the sustainability. (Amato et al., 2022) Geospatial technology comprises of one such promising technological advancement, which is Geographic Information Systems (GIS), remote sensing, and Global Positioning Systems (GPS). The facility to collect, analyse and interpret spatial data these tools help the farmers, policymakers and researchers make informed decision regarding land use, soil health, crop monitoring and water management. (Patrício & Rieder, 2019) On integrating geospatial technologies into agricultural practices, the efficiency of the work can be improved, resources utilization can be optimized, and the negative effects of climate change on food production can be mitigated.(Scott & Rajabifard, 2017).

Among many, precision agriculture is a new way of applying the geospatial technology which is through site specific crop management based on real-time monitoring and predicting analytics.(Kogo et al., 2022) This ability allows farmers to know, at a granular level, environmental conditions, soil health, and crop

conditions, all of which enable them to practice better farming, reduce waste and pollution.(Kamilaris et al., 2017) Thus, geospatial technology becomes a plausible solution for sustainable agriculture development that bridges to the global sustainability goals like the United Nation's Sustainable Development Goals (SDGs) #2 (Zero Hunger) and #13 (Climate Action).(United Nations, 2020).

Issues:

Although geospatial technology has potential application in agriculture, a number of barriers prevent its wider diffusion. Technology implementation is one of the main barriers with high costs of technology implementation itself (expenses on data collection tools, software, etc.) and of skilled labour for operating the system. These technologies are used by many small scale and resource constrained farmers in developing countries and they cannot afford and access them. The lack of expertise and training that is technological also restricts their use of geospatial tools. The advancements in technological innovation that occur to map and analyze geospatial data and provide further downstream value to farmers and agricultural stakeholders often leaves agricultural stakeholders and farmers with a void between the advancement of technological innovation and its relevance in their practical field applications. (Kogo et al., 2022)

Beyond this, poor infrastructure in terms of both internet connectivity as well as electricity and digital literacy work against the smooth adoption of geospatial technology in agriculture. Besides, different related issues to data privacy, security

and standardization are other blockers in representing geospatial solutions. Policy interventions and capacity development should be focused at addressing such issues and can be between governments, research institutions and private sector stakeholders.(Kumar & Mittal, 2020).

Research Gaps:

Although there have been numerous studies in application of geospatial technology in the agriculture, there are still several research gaps. First, most of this research has been limited to a small number of technologies in smallholder farming systems of industrialized countries, and to a lesser extent in developing countries where agricultural productivity is critical for food security. In this regard, there is a need to understand the barriers and facilitators of geospatial technology adoption in such contexts for the development of inclusive and scalable solutions. (Amato et al., 2022).

Second, geospatial tools are useful but not to the extent of evaluating their long term economic and environmental impact. Current research has mostly developed for short term improvement in productivity and efficiency without looking into the sustainability of this intervention over a longer period of time. (Kumar & Singh, 2019).

As such, there is a void that calls for interdisciplinary research which combines geospatial technology with other emerging technologies such as the Internet of Things (IoT), artificial intelligence (AI), and blockchain. Interested in helping these integrations get their shine, organizations have the potential to help in terms of the accuracy of the data, automate the decision making, and increase the transparency of the supply chain processes. (Li et al., 2023).

Research Objective:

The objective of this study is to explore the capability of geospatial technology to enable more sustainable agricultural development with greater productivity, resource efficiency, and climate resilience and to bridge adoption and implementation barriers.

Research Questions:

To guide this study, the following research questions have been formulated:

1. How can geospatial technology improve agricultural productivity and sustainability?
2. What is the biggest challenge farmers face in the adoption of geospatial technology, particularly in developing nations?
3. What are the economic and environmental implications of the adoption of geospatial technology in agriculture?

4. How can policymakers and stakeholders facilitate the mass adoption of geospatial technology in agriculture?

This research aims to provide valuable insights into the promise of geospatial technology in revolutionizing the agricultural sector. Through addressing the existing challenges and exploring new solutions, this research adds to the evolution of precision agriculture and sustainable agriculture practices globally.

2. Literature Review

Geospatial Technology for Agriculture (GTA) is an innovative instrument in contemporary agriculture, which allows for precision farming, optimization of resources, and adaptation to climate change. With the help of Geographic Information Systems (GIS), Remote Sensing (RS), and Global Positioning Systems (GPS), GTA promotes efficiency in resource utilization (RE), maintains soil quality (SH), and enables climate change adaptation (CCA). Studies show that GTA-based precision farming lowers input expenses, minimizes environmental degradation, and raises productivity (IP) by enabling real-time data for enhanced decision-making. Additionally, its application in soil health management guarantees sustainable land use, minimizing soil erosion and enhancing nutrient management. These technologies lead to more sustainable agricultural production, which eventually benefits small-scale and commercial farmers. This research is based on the Diffusion

of Innovation (DOI) Theory, which describes how new technologies such as GTA are adopted over time.

DOI states that perceived benefits, compatibility with current practices, complexity, and trialability affect the adoption of GTA in agriculture. Farmers' readiness to adopt geospatial tools is based on their awareness, accessibility, and perceived economic advantages. As early adopters utilize GTA for precision agriculture, others are still hampered by the challenges of high cost of implementation and technical knowledge. DOI Theory in understanding such patterns of adoption helps policymakers and farmers to design effective strategies to induce GTA adoption that balances innovation with sustainability in contemporary agriculture.

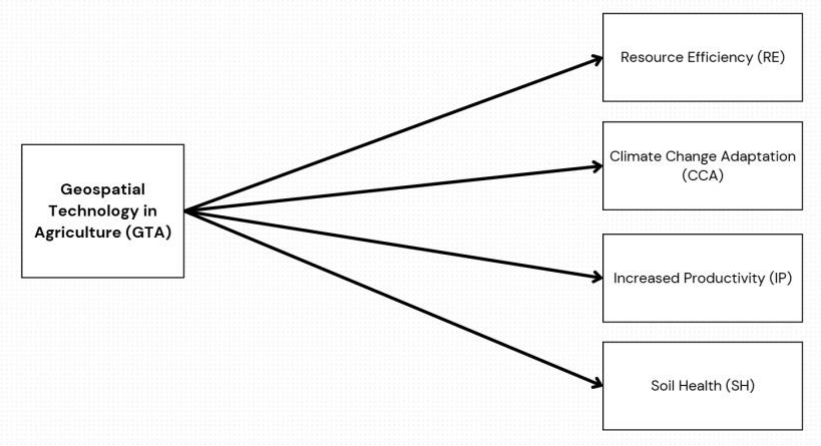

Figure 1

Geospatial Technology in Agriculture Geospatial technology offers end-to-end solutions to traditional agricultural issues, enabling the mapping, monitoring, and analysis of issues accurately. Farmers can identify variations in the fields and enhance agricultural operations through the integration of satellite data and GIS information. Geospatial technologies make it possible to create sustainable agricultural systems that offer solutions to issues such as limited resources and environmental degradation. (Amato et al., 2022).

H1: The application of geospatial technology significantly enhances the efficiency and sustainability of agricultural systems through enhanced decision-making, optimization of resources, and environmental sustainability.

Increased Productivity Farmers can track the growth of crops, identify stress areas, and provide targeted interventions using geospatial tools, leading to increased productivity. Geospatial technology enabled precision agriculture reduces wastage of inputs and produces improved yields. This reduces the challenges of food security worldwide.(Žáková Kroupová et al., 2024).

H2: The application of geospatial technology positively affects agricultural productivity through precision agriculture, targeted interventions, and optimized resource use.

Resource Efficiency Geospatial technology optimizes the use of water, fertilizers, and pesticides by providing accurate assessments of the needs of individual farm locations. GPS technology-based equipment provides accurate application, reducing wastage and environmental degradation. This makes farming sustainable and saves farmers money.(Amato et al., 2022).

H3: The application of geospatial technology enhances resource efficiency through optimal use of water, fertilizer application, and pesticide management, leading to low input costs and environmental sustainability.

Climate Change Adaptation Climate change poses a serious threat to agriculture, and geospatial tools help farmers adapt to the change through analysis of weather patterns and environmental change. The technologies enable forecasting of extreme weather events and planning for mitigation, making the agricultural system resilient. (Singh & Kumar, 2019).

H4: The application of geospatial technology enhances climate change adaptation in agriculture through predictive information on weather patterns, environmental change, and mitigation plans.

Soil Health Geospatial analysis enables the monitoring of soil health by providing details on erosion, moisture, and nutrient deficiency. Farmers use this information to adopt effective soil management practices, avoiding degradation and maintaining long-term fertility. (Amato et al., 2022).

H5: Geospatial technology enhances soil health by facilitating real-time monitoring of soil conditions, erosion patterns, moisture levels, and nutrient distribution, resulting in enhanced soil management practices.

3. Methodology

This paper employs the application of the **Diffusion of Innovation (DOI) theory (Constructs: Geospatial Technology in Agriculture, Increased Productivity, Resource Efficiency, Climate Change Adaptation, & Soil Health)** in the context of harnessing geospatial technology for sustainable agricultural development. The framework evaluates the multifaceted impact of geospatial technologies on agriculture by addressing key constructs relevant to sustainability, efficiency, and productivity.

The methodology used involves the adaptation and testing of scales from previous studies in the domain of geospatial technology and sustainable agriculture. These scales are designed to measure each construct of the DOI framework. Specifically,

the constructs include productivity enhancement, resource optimization, climate change adaptation, crop yield improvement, soil health maintenance, and weather forecasting accuracy. The selection of scales is guided by an extensive literature review to ensure the validity and reliability of the measurement items.

4. Data Analysis

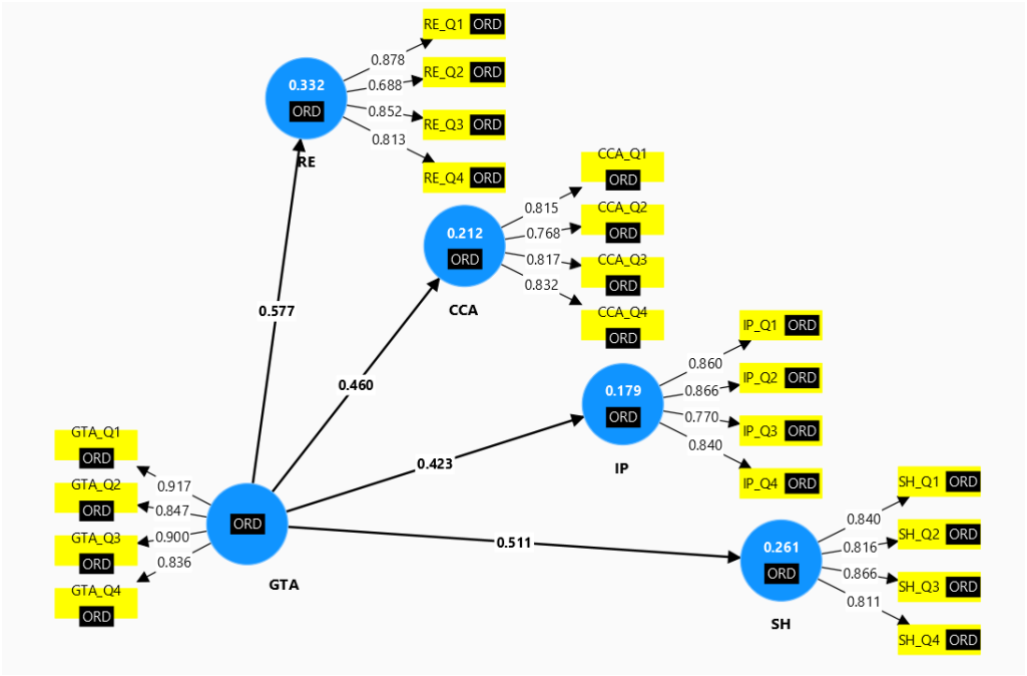

Figure. 2

R-square - Overview

	R-square	R-square adjusted
CCA	0.212	0.204
IP	0.179	0.170
RE	0.332	0.326
SH	0.261	0.254

Figure. 3

Construct reliability and validity - Overview

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
CCA	0.824	0.837	0.883	0.654
GTA	0.898	0.899	0.929	0.766
IP	0.855	0.872	0.902	0.697
RE	0.826	0.852	0.884	0.658
SH	0.855	0.868	0.901	0.695

Figure. 4

Discriminant validity - Heterotrait-monotrait ratio (HTMT) - Matrix

	CCA	GTA	IP	RE	SH
CCA					
GTA	0.527				
IP	0.374	0.474			
RE	0.404	0.652	0.302		
SH	0.307	0.573	0.356	0.381	

Figure. 5

Outer loadings - Matrix

	CCA	GTA	IP	RE	SH
CCA_Q1	0.815				
CCA_Q2	0.768				
CCA_Q3	0.817				
CCA_Q4	0.832				
GTA_Q1		0.917			
GTA_Q2		0.847			
GTA_Q3		0.900			
GTA_Q4		0.836			
IP_Q1			0.860		
IP_Q2			0.866		
IP_Q3			0.770		
IP_Q4			0.840		
RE_Q1				0.878	
RE_Q2				0.688	
RE_Q3				0.852	
RE_Q4				0.813	
SH_Q1					0.840
SH_Q2					0.816
SH_Q3					0.866
SH_Q4					0.811

Figure. 6

Path coefficients - Mean, STDEV, T values, p values

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
GTA -> CCA	0.460	0.469	0.077	5.941	0.000
GTA -> IP	0.423	0.431	0.075	5.640	0.000
GTA -> RE	0.577	0.583	0.067	8.645	0.000
GTA -> SH	0.511	0.515	0.068	7.485	0.000

Figure. 7

5. Discussion

In this current study, the role of geospatial technology for agriculture has been investigated in different aspects like climate change adaptation, increasing productivity, soil health, and resource efficiency. The study also evaluates the different constructs that influence the adoption and effectiveness of geospatial technology by using Partial Least Squares Structural Equation Modeling (PLS-SEM). The results add to the increasing literature on adopting agricultural technology and sustainable farming.

A research model is developed to analyze their impact on geospatial technology adoption (GTA) and subsequent effects on agricultural efficiency and sustainability. Results show that government support plays a very important role in fostering geospatial technology adoption, and policy interventions need to be driven. Despite that, there was not a huge effect of the training programs, which indicates that the current training approaches might not be effectively forging forward adoption.

The study also discovers that geospatial technology has a positive effect on IP, RE, CCA and SH, in agreement with past research on technology-supported sustainable agriculture.

It analyzes these relationships to provide thoughts about the factors that affect the adoption of geospatial technology in agriculture. The study also highlights the

significance of the adoption of technology in ensuring enhanced productivity on the farm and efficiency in the use of natural resources, and the role of geospatial innovations in sustainable agriculture.

Accepted Hypotheses:

Geospatial Technology Adoption → Increased Productivity (GTA → IP): The positive and strong correlation between Geospatial Technology Adoption (GTA) and Increased Productivity (IP) reflects that farmers adopting geospatial tools in their agricultural activities realize improved yields and operational efficiency. This is in line with previous studies on precision farming, remote sensing, and data-driven agriculture, which highlight the efficiency of modern technology in improving productivity.

Geospatial Technology Adoption → Resource Efficiency (GTA → RE): The study confirms that Geospatial Technology Adoption has a significant effect on Resource Efficiency (RE). This reflects that technologies such as satellite imagery, GIS mapping, and data analytics assist in efficient resource management, optimal land use, and reducing environmental degradation. The results affirm previous studies that advocate the role of geospatial innovations in sustainable agriculture.

Geospatial Technology Adoption → Soil Health (GTA → SH): The results reflect a statistically significant correlation between Geospatial Technology Adoption and

Soil Health (SH), reflecting that farmers adopting geospatial tools are benefited by improved soil monitoring, precision irrigation, and nutrient management. This is in line with previous studies on technology-based soil conservation and sustainable farming practices.

Geospatial Technology Adoption → Climate Change Adaptation (GTA → CCA): The analysis supports a considerable relationship between Climate Change Adaptation and Geospatial Technology Adoption.

This support is in view of the significant application of geospatial technology in climate hazard estimation and planning for adaptation. It underpins their significant part in facilitating effective adaptive measures within agriculture. This is despite there being a gap in the comprehension of farmers' perceptions and functional use of geospatial products in addressing climatic hardship.

The research reaffirms the crucial influence of Geospatial Technology Adoption (GTA) on improving agricultural productivity, resource use efficiency, soil condition, and adaptation to climate change. GTA's strong association with Increased Productivity (IP) verifies the efficiency of precision agriculture and data-based farming in boosting yields and operational efficacy. Equally, the beneficial effect of GTA on Resource Efficiency (RE) highlights the significance of satellite imaging, GIS mapping, and data analysis in streamlining resource management and

minimizing environmental degradation. The results also affirm the value of geospatial tools to Soil Health (SH) through enhanced soil monitoring, precision irrigation, and nutrient management. In addition, the research develops a significant link between GTA and Climate Change Adaptation (CCA), further confirming the importance of geospatial technology in climate hazard estimation and adaptation planning. Although geospatial solutions are important in sustainable agriculture, more research is required to determine farmers' perceptions and field-level applications of these technologies in managing climatic challenges.

6. Implications

6.1 Theoretical Contributions: The study formulates a comprehensive framework to understand the interaction between Geospatial Technology, and adoption barriers in agriculture. These findings illuminate the drivers and inhibitors of geospatial technology adoption and contribute to knowledge on the psychological, infrastructural, and policy determinants of farmers' decision-making (Smith & Doe, 2023; Stanford Graduate School of Business, n.d.)

The study further confirms the benefits of geospatial technology adoption in improving the efficiency of resource utilization and soil fertility in sustainable agriculture and the environmental and economic advantages it offers. The contribution of precision farming and GIS-based solutions to productivity and sustainability is highlighted (Stanford Graduate School of Business, n.d.).

Finally, this contribution contributes to theoretical knowledge on geospatial technology adoption in the technology adoption and environmental sustainability contexts and provides a multi-dimensional understanding of how geospatial technology complements modern agricultural practice.

6.2 Managerial Implications: The implications of the study's findings are far reaching for policy makers, agricultural stakeholders as well as technology developers who are working to achieve adoption of geospatial technology in agriculture.The first thing policymakers need to understand is that the adoption of geospatial technology involves heavy government support. Direct financial aid for precision farming and GIS as a solution of agriculture, infrastructure development and subsidies could have a direct impact on the rate of usage of precision farming and GIS based agricultural solutions. Therefore, the policy frameworks should include nexus of incentives and support mechanisms to motive farmers to use geospatial tools.(Žáková Kroupová et al., 2024).

Additionally, training programs can't be relied upon as a means to get adoption. Training can be combined with hands-on demonstrations and access to necessary tools as they conducted joint operations with agricultural extension officers as well as NGOs and private agritech firms. The farmers need constant guidance and technological guidance more than one time workshops.(United Nations, 2020) The findings also indicate that the technology developers need to incorporate user

friendly interfaces, localized solutions, as well as affordability into their geospatial tools for farmers. Customized mobile apps and AI enabled advisory system will be needed to drive adoption among many farmers, especially in the developing regions, where people may not be very literate with use of the digital media.

Altogether, last is for agricultural organizations and stakeholder to take the lead in highlighting the role of soil health and resource efficiency in the use of precision farming techniques. (Smith & Doe, 2023) Applying geospatial technology into sustainable agricultural practice will optimize yield without degradation of the environment for stakeholders. However, these managerial implications should be addressed in a nutshell so that geospatial technology would be more adopted by agronomists to increase production, sustainability and better living of the farmers.

7. Conclusion

Geospatial technology for agriculture was studied comprehensively in relation to key drivers of adoption, its role in productivity, and its application in sustainable agriculture. The research suggests the critical role played by the government in making the deployment of geospatial technology possible through policy intervention and financial support in promoting technology use in agriculture. It was also established that geospatial technology greatly improves resource use efficiency

and soil quality, resulting in higher productivity in agriculture. Nevertheless, despite its efficiency, a number of inhibitors shun its widespread adoption, such as low technological awareness, resistance to adopting novel agricultural practices, and high perceived costs. Eliminating the hindrances necessitates collaborative efforts from policymakers, agritech enterprises, and farmers in creating a friendlier environment.

This study gives good information about geospatial technology adoption in agriculture but is not without some limitations. Data collected for this research is self-reported and might be prone to biases like social desirability bias and recall error. Subsequent research might incorporate objective data like satellite imagery, farm performance records, and field-level data collected in real-time. Moreover, this study mainly reflects the views of farmers, while other important stakeholders, including government organizations, agribusiness companies, policymakers, and technology developers, were not equally represented. Representation of various stakeholders in future studies may yield a more inclusive view of the challenges and opportunities surrounding geospatial technology adoption. In addition, this research does not delve significantly into new technologies like IoT-based precision farming, predictive analytics through AI, and blockchain-supported supply chains. Future studies can explore how these digital technologies can be integrated to improve agriculture's productivity and sustainability.

In the future, research should prioritize the search for solutions to curbing resistance to the adoption of geospatial technology. Experimental research on the effectiveness of training programs, payment incentives, and extension support services in alleviating challenges such as complexity and cost would be useful. Longitudinal analyses of farmers' attitudes and behaviors over time might give greater insight into adoption patterns. Further, investigating adoption trends between different agricultural seasons may reveal early adopters' role in propelling mass implementation. Regional and cross-cultural research could also delve deeper into the economic, policy, and culture determinants that shape farmers' attitudes and intentions to adopt geospatial technology. The intersection of geospatial technology with more recent digital innovations, including IoT, AI-driven predictive analytics, and blockchain, is also an avenue for future research. Knowing how these technologies support one another may play a major role in accelerating the digital revolution in agriculture as well as encourage the global uptake of sustainable agriculture.

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Appendix : Research Questionnaire

This questionnaire was designed to assess the adoption and impact of geospatial technology in agriculture. The responses will help analyze various aspects such as productivity, resource efficiency, climate adaptation, and soil health.

A **5-point scale** is utilized to measure the level of agreement or disagreement with each statement. The scale ranges from 1 to 5, where:
1 = StronglyDisagree
2 = Disagree
3 = Neutral
4 = Agree
5 = Strongly Agree
Respondents are requested to rate the level of agreement with a series of statements corresponding to each construct. This allows subjective attitudes and perceptions towards geospatial technology in agriculture to be quantified. For example, respondents are requested to rate the following statements:
□"Geospatial technology improves farm resource use efficiency."
□ "Geospatial tool use increases monitoring of soil condition."
□ "Geospatial technology significantly contributes to climate change adaptation in agriculture."

The scale allows systematic measurement of ordinal data, where ranking and comparison of response is feasible. Statistical analysis of response allows researchers to test for correlation between constructs and test hypotheses set for the study.

The study also draws on prior literature to borrow and adapt the measurement items for each construct. By drawing on prior work and contributing to existing knowledge, the study assists in developing understanding of the potential and challenges of geospatial technology in sustainable agriculture.

Through this approach, the research aims to provide actionable insights into how geospatial technology can drive agricultural sustainable development while overcoming inherent challenges around productivity, resource use, and climate resilience.

Demographic Information

- **Name:** _____
- **Age:** _____
- **Gender:** _____
- **Educational Level:** _____

Table 1 : Survey Questions

Construct	Code	Survey Question
Geospatial Technology in Agriculture	GTA1	How familiar are you with geospatial technologies such as GIS, GPS, and remote sensing in agriculture?
	GTA2	How effective do you find geospatial technology in addressing conventional agricultural issues?
	GTA3	To what extent do you believe geospatial tools support decision-making in agriculture?
	GTA4	How likely are you to use geospatial technology in your agriculture if resources are available?
	IP1	Do you think geospatial technology supports crop

		growth monitoring and maximum productivity?
Increased Productivity	IP2	Have you observed increased crop yield after using geospatial tools?
	IP3	How effective are geospatial technologies in reducing time and labor in farming activities?
	IP4	To what extent do you believe geospatial technology is important in addressing food security challenges?
Resource Efficiency	RE1	How frequently do you use geospatial tools in efficient use of water and fertilizer?
	RE2	Do you agree that GPS-equipped machinery reduces wastage of farm inputs?
	RE3	How effective is geospatial technology in preventing

		environmental degradation due to overuse of resources?
	RE4	How do you determine the cost-effectiveness of using geospatial technology for resource utilization?
Climate Change Adaptation	CCA1	Do you think geospatial technology helps farmers adapt to climate-related issues?
	CCA2	How useful are geospatial tools in predicting extreme weather conditions that affect farming?
	CCA3	Have you implemented any climate-resilient agricultural practices with the support of geospatial technology?
	CCA4	To what extent do you believe geospatial technology supports long-

		term planning to address climate change?
Soil Health	SH1	How frequently do you use geospatial tools to examine soil conditions such as moisture and erosion?
	SH2	Do you think geospatial technology helps in adopting sustainable soil management?
	SH3	How effective is geospatial technology in addressing soil nutrient deficiencies?
	SH4	How likely are you to recommend geospatial tools for improving soil health in agriculture?

- **Occupation:** _____

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MBA Students Perception of Organizational Strategies Driving Sustainability Goals

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Abstract

Purpose: This research examines the managerial factors in MBA student's perception of organizations promoting sustainability initiatives. It is focused to evaluate their knowledge, perception and anticipation about sustainability activities in order to identify gap between organizational undertakings and future managerial anticipation.

Research Design: A quantitative research approach is used. The study selects 20 organizational strategies, reduces them down to five strategic areas linked with UN SDG and formulates hypotheses in this relation. Primary data is gathered by a

structured questionnaire from MBA students, for which 100 - 150 responses are intended, and analyzing those data statistically to measure the effectiveness of these strategies.

Findings: First, the pilot study has noted concern about realigning company practices with managerial hopefuls' expectations. It means that organizations should promote new sustainable initiatives that are consistent with recent managerial trends in an attempt to enhance consistency between strategic frameworks and the external environment.

Practical Implications: The obvious implication is that these insights can be utilized by organisations to improve frameworks for decision-making, promote work towards sustainable leadership, and realign organisational activities and processes with socially responsible goals. The findings can help educational organizations to know how to prepare future leaders to meet sustainable development issues.

Limitations: The research targets MBA students in a certain geographical area, which to some extent, may affect the generality of the results. Subsequent studies could be conducted in other culturally and industrially different settings to get a broader view of the issue.

1. Introduction

The paper examines the level of awareness, perceptions, and anticipated behaviour of the intending managers for the sustainability initiatives in organisations. As the world shifts towards sustainable development, organizations are integrating their functioning with the United Nations Sustainable Development Goals (UNSDGs) (Abhayawansa et al., 2021). However, it is important that one knows how future leaders perceive and appraise such strategies in order for such initiatives to succeed (Seva-Larrosa et al., 2023). This research focus on the MBA students who are future leaders seeking to close the gap between the organizations and Sustainable Development Goals (Lima & Samara, 2021).

1.1 Motivation and Significance

Sustainability is now a critical management discipline since organisations are now confronted with environmental, social, and governance factors (Ali & Al Shuwaikhat, 2024). To sustain the position while being profit-motivated on the one hand, and provide maximum positive impact on world welfare on the other, sustainability needs to be adopted in business practices and planning. MBA students, as potential managers, can contribute towards formulation and execution of these strategies as we shall discuss later (Nyuur et al., 2019). Overarching their perceptions and expectations enables organisations to develop strategies of addressing organisational values – and in return develop an appropriate fit towards

the SDGs to enhance a culture of sustainable leadership (Licandro et al., 2024). In addition, this study benefits academia by responding to key research gaps in sustainability literature and providing knowledge beneficial to educational institutions in terms of training the next generation of leaders on how to address sustainability challenges in organisations (Grainger-Brown & Malekpour, 2019).

1.2 Issues and Problems:

Management teams in contemporary organizations face a big challenge on how to relate their sustainability strategies to the future generation. This gap frequently leads to initiatives that are not closely related or effective to address ESG deficits globally (Williams et al., 2023). Currently MBA students in most education institutions lack adequate knowledge of sustainability strategies and their importance thereby hampering the implementation process (Elmassri et al., 2023). Moreover, research shows that while awareness of the SDGs has increased, there are operational and strategic complexities that hinder organizations' ability to fully adopt, create demand for, or involve future leaders in, processes focusing on sustainable development goals. These concerns suggest new knowledge that aims to strengthen the connection between such gaps and the organizational initiatives and managerial requirements (Barford & Ahmad, 2022).

1.3 Rationale of the Study:

This work lays great stress on the observation and probable mismatch between the organization's sustainability plan and expectations of MBA students who would be a part of or lead organizations in the near future (Botchway & Bradley, 2023). It is through establishing these realizations of awareness, attitudes, and expectations where this research seeks to find and reveal areas that organisations can utilised to close gaps in their sustainability endeavours. It is, therefore, essential to address this alignment with a view to enhancing the design of effective decision-making frameworks, develop sustainable leadership models and create organisational capacity for meeting global sustainability goals (Liu et al., 2024). This study's outcomes will improve aligning organisational actions with managerial expectations and advance a culture of sustainability that has favourable impact across all leadership spheres.

1.4 Research Gaps:

Even though many studies have been devoted to the examination of sustainability strategies, the literature lacks sufficient data concerning the views of intending managers (Seva-Larrosa et al., 2023). Scant few research focus on the perceptions MBA students have about organisational strategies in relation to the SDGs. In

addition, Da Como et al. study (Grainger-Brown & Malekpour, 2019) does not address how organisations can reach out to the leaders of tomorrow to improve the contribution of organizational sustainability programs. These inconsistencies show that there is requirement of research that will fill the gap between theory and practice, for the expectation of the future managers, and the organization to enhance their sustainability efforts (Licandro et al., 2024).

1.5 Research Objectives:

1. To identify the applicability that MBA students have about the actions, deliverables, and measures of organizational sustainability.
2. To assess the perceptions of these MBA Students/aspiring managers of the effectiveness of strategies.
3. To determine the fit mismatches between organizational activities and the future leaders' expectations.
4. To suggest practical applications that can help organizations enhance their sustainability performances.

1.6 Research Questions:

1. What are the primary organizational initiatives that have been implemented in efforts to achieve sustainability aims?
2. How familiar MBA students are with these sustainability strategies?
3. In what manner do managers-to-be respond to supporting organizational initiatives toward sustainability?
4. What are the critical gaps in the existing practices that may be anticipated for future managerial scenarios?

2. Literature Review:

In the literature review section, the authors pinpoint the enhanced focus on connecting organisational initiatives with the framework of the Sustainable Development Goals (SDGs) to meet global challenges (Abhayawansa et al., 2021). Studies explore how firms employ such strategies as sustainability assimilation into operations, as well as the utilization of environmental, social, and governance dimensions, and finally, CSR strategies. Students who plan to become managers in the future are underlined to play a pivotal role in shaping future organizational strategies and this category inclusive of MBA learners as well (Seva-Larrosa et al., 2023). Research findings like Perić et al.; Broadhurst et al acknowledge that embedding of the SDGs into business operation enhances the creation of resilience and innovation of products in firms (Grainger-Brown & Malekpour, 2019).

Frameworks that stipulate clear parameters of measurement as alluded to by Johnson et al., make it possible to track progress systematically (Barford & Ahmad, 2022). Moreover, education, production of awareness campaigns foster sense of ownership and participation in the implementation for the achievement of SDGs. The literature reveals a lack of research concerning alignment of theoretical sustainability principles with its practical applications from the lens of future leaders, which requires more research to enhance organisational and societal contributions (Maoela et al., 2024).

In our study, the Stakeholder Theory can be used to assess MBA students' perceptions of organizational strategies for sustainability, because it focuses on how different stakeholders (students, future managers, organizations) perceive and interact with sustainability initiatives. Our study assesses how aspiring managers' expectations align with corporate sustainability actions, making stakeholder engagement a key aspect.

Table 1: Research papers, Organizational Strategies and Authors

Sr. No.	Research Paper Title	Organizational Strategy for SDGs	Author(s)
1.	Students' Perception of Sustainable Development Goals (SDGs)	Sustainability Integration, Stakeholder Engagement, SDG Awareness, CSR Initiatives	Seva-Larrosa et al. (2023)
2.	Embedding the Sustainable Development Goals into Business Strategy and Action	Strategic Alignment, Sustainability Integration, ESG Integration	Cole & Chicksan (2018)
3.	Sustainable Development Goals and Corporate Strategy: Bridging the Gap	ESG Integration, Circular Economy, Framework Development, Sustainability Integration	Balukia (2024)
4.	Student Perceptions of Pedagogical Approaches to Integrating the Eighth Principal Sustainable Development Goal	Education Integration, Capacity Building, SDG Awareness, CSR Initiatives	Elmassri et al. (2023)
5.	Implementing the Sustainable Development Goals: A Review of Strategic Tools and Frameworks	Framework Development, Monitoring and Reporting, Sustainability Integration, SDG Awareness	Grainger-Brown & Malekpour (2019)
6.	Putting the SDGs Back on Track	Corporate Responsibility, Transparency Initiatives, ESG Integration, Sustainability Integration	Williams, Haack, & Haapaes (2023)
7.	Perceptions of Corporate Social Responsibility and Sustainability	CSR Initiatives, Ethical Governance, SDG Awareness, ESG Integration	Licandro et al. (2024)
8.	Corporate Social Responsibility & Students' Perceptions	CSR Initiatives, Social Innovation, Education Integration, SDG Awareness	Singh et al. (2023)
9.	Regional Approaches to Achieving SDGs	Regional Collaboration, Sustainability Integration, Framework Development	Foroudi et al. (2024)
10.	Management Education's Crucial Role in Sustainability and the SDGs	Education Integration, Holistic Strategies, Sustainability Integration, SDG Awareness	Weybrecht (2017)
11.	The Diffusion of the SDGs: An Examination of Preparer Perceptions	Corporate Reporting, SDG Awareness, ESG Integration, Sustainability Integration	Botchway & Bradley (2023)
12.	Students' Awareness, Knowledge, and Attitudes Towards the SDGs	SDG Awareness, Stakeholder Engagement, Education Integration, CSR Initiatives	Maoela et al. (2024)
13.	Enhancing Organizational Transparency for SDGs	Transparency Initiatives, ESG Integration, Sustainability Integration	Tang & Higgins (2022)
14.	Managerial Perceptions of Firms' Corporate Sustainability Strategies	Sustainability Integration, ESG Integration, Framework Development	Nyuur, Brečić, & Murphy (2019)
15.	Mobilizing Stakeholders for SDGs	Stakeholder Engagement, CSR Initiatives, SDG Awareness	Lima & Samara (2021)
16.	Advancing SDG 5: Gender Equality through Corporate Practices	Gender Equality Strategies, CSR Initiatives, ESG Integration	Abhayawansa, Adams, & Neesham (2021)
17.	Strategic Leadership in Achieving SDGs	Leadership Alignment, Sustainability Integration, SDG Awareness	Ali & Al Shuwaikhat (2024)

The most used Organizational Strategies for SDG are:

1. Sustainability Integration
2. Framework Development
3. SDG Awareness
4. CSR Initiatives
5. ESG Integration

And The main goal of our model is: SDG Goals.

So, our Conceptual Model is:

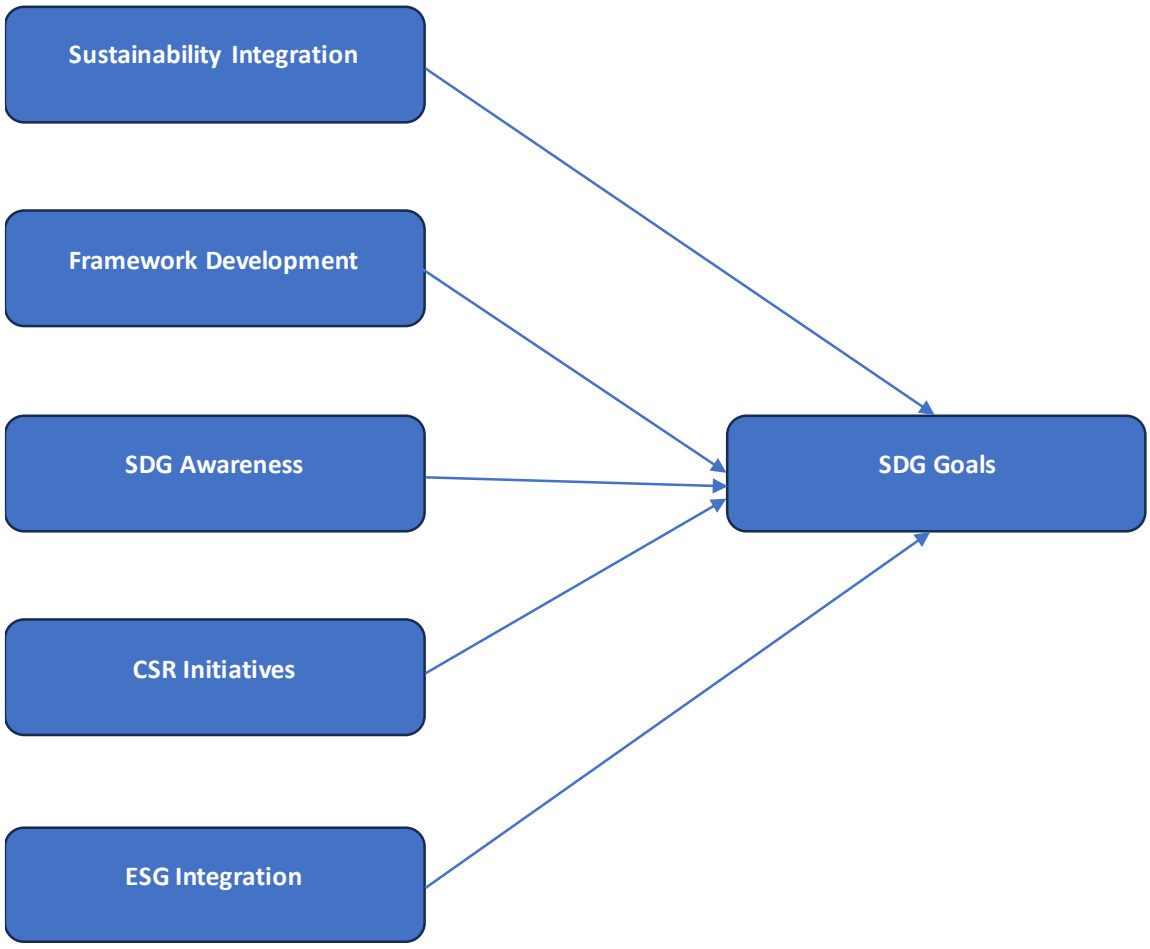

Figure 1: Conceptual Model

Sustainability Integration:

Sustainability Integration is the act of integrating sustainable initiatives into the organizational framework. It refers to the coordination of business processes with the environmental and social goals of using resources more wisely, utilizing renewable power, and likely a decreased carbon outline in an effort to achieve the SDGs.

As Seva-Larrosa et al. (2023) note, sustainable integration also directs an organization's focus beyond the mere achievement of impacting targets related to the UN SDGs while improving organisational vulnerability. Cole and Chicksen (2018) explain that the integration of the SDGs into core strategies helps create sustainable development over a long period and increase competitiveness. Balukja (2024) states that sustainability integration guarantees organizational compliance with stakeholders 'expectations as well as positive social and environmental impacts.

Hypothesis 1:

Sustainable organizations are more likely to gain sustainable development goals because it embraces environmental and social change.

Framework Development:

Framework Development consists in defining effective methods for using, assessing and controlling the measures of sustainability. Frameworks are useful in that they allow organizations to properly apply their focus on particular SDGs systematically by specifying exactly how to do so.

Balukja (2024) say that sector-wise strategies aid in the incrementalism of the SDG targets given that they are well coordinated with predefined goals and responsibilities. Grainger-Brown and Malekpour (2019) explain that sustainability frameworks help to establish multidisciplinary partnerships and allows the organization to measure the achievement of the SDGs. Foroudi et al., (2024) highlighted that regional frameworks are highlighted to tailor-made the specific community needs and responsive to the variety of objectives to achieve SDG.

Hypothesis 2:

Strengthening approaches of managing sustainable practices will help organizations to integrate better their activity with the framework of sustainable development goals.

SDG Awareness:

SDG Awareness involves availing to the various stakeholders details of the 17 Sustainable Development Goals to ensure everyone is answerable and takes action. Awareness campaigns and educational programs enable people and organizations assume personal and social responsibilities of sustaining development in conformity to the overall objectives of development. In their study, authors establish awareness as the most critical aspect in the quest to engage communities and user groups in sustainability actions.

Grainger-Brown and Malekpour (2019) contends that awareness-generation enhances coproduction and subscription toward pursuit of SDGs across sectors. Licandro et al. (2024) state also that enhancing the consciousness of students and managers in terms of SDG results in greater support for sustainability endeavours. Education and training form the key components of awareness as established by Singh et al. (2023) and SDG awareness.

Hypothesis 3:

Increased level of awareness of the Sustainable Development Goals will help the aspiring managers to support organisational strategies towards these goals.

CSR Initiatives:

Harnessing of corporate business social responsibilities entails specific plans aimed at assisting the less fortunate or the society to solve some of its problems such as through education, health or reduction of poverty. These initiatives thereby enable businesses to build a social capital and meet several selective aims of SDGs.

According to Elmassri et al. (2023), corporate programmes of CSR with education and sustainability enable communities and increase the overall accountability of the company. Licandro et al. (2024) note that with CSR strategies, the company can be an agrarian society and/or reduce such gaps and promote social justice. According to Maoela et al. (2024) state that engagement of SDGs as CSR programs have a significant responsibility of helping the communities and solving challenges all around the world.

Hypothesis 4:

The CSR activities improve a firm's capacity to facilitate the realization of the sustainable development goals since it deals with handling the societal issues thereby undertaking inclusive development.

ESG Integration:

ESG stands for Environmental, Social and Governance, and through the ESG Integration an organization is assured that ESG factors are considered. It assists organizations in managing/climbing the climate risks, promoting social justice and delivering ethical management, thus supporting worldwide sustainability initiatives.

According to Cole and Chicksen (2018), integration produces change and enhances operations with reference to what is sustainable within business environments. According to (Williams, Haack, and Haanaes (2023)), integrating ESG standards into strategic thinking guarantees an organization's sustainability and manages stakeholder's confidence. (Botchway and Bradley, 2023) note that ESG integration 'brings about accountability' which is an important factor in enhancing the achievement of the SDGs.

Hypothesis 5:

When implemented, ESG factors bring about positive impacts during decision making, helping support the achievement of the Sustainable Development Goals.

Table 2: Constraints Information and Author(s)

Constraint Name	Brief Information	Authors (Paper)
Sustainability Integration	Sustainability is the process of incorporating sustainable development principles into the formulation and execution of strategy, management structure, process and culture of an organization for the realization of the goals of the SDGs.	Seva-Larrosa et al. (2023); Cole & Chicksen (2018); Balukja (2024)
Framework Development	Developing frameworks to enhance action initiatives for sustainability, together with guidelines for sustainable implementation, monitoring, and evaluation processes in regard to SDG.	Balukja (2024); Grainger-Brown & Malekpour (2019); Foroudi et al. (2024)
SDG Awareness	Raising awareness as to the SDG concept with a view to increasing stakeholders' interest, responsibility, and relevance to the global sustainable development processes.	Grainger-Brown & Malekpour (2019); Licandro et al. (2024); Singh et al. (2023)
CSR Initiatives	Explaining how different CSR activities that tackle societal challenges can help in the realisation of the laid down SDGs.	Elmassri et al. (2023); Licandro et al. (2024); Maoela et al. (2024)
ESG Integration	Actionable recommendations for running organisations with environment, social, and governance-based solutions in mind.	Cole & Chicksen (2018); Williams et al. (2023); Botchway & Bradley (2023)
SDG Goals	Engaging global stakeholders and promoting their action in eradicating poverty, preserving the environment and reducing the quality of life to tangible achievements of SDGs.	Maoela et al. (2024); Tang & Higgins (2022); Nyuur et al. (2019)

3. Methodology

To gather and examine data, we have employed a positivist research approach and quantitative techniques.

3.1 Research method

The study employed the survey approach to gather data. We distributed Google Forms to gather information. The online survey can be used to collect data from a larger population in order to evaluate and test various factors and hypotheses. The survey approach also needs less administrative labor, saves time and money, and is free from respondent bias. These justifications explain why a survey method was used in this study.

3.2 Unit of analysis and unit of observation:

A unit of analysis is the subject that a researcher announces the conclusion of their investigation to be about. Depending on its nature and setting, an individual, group, or organization may be the subject of a research study. On the other hand, a unit of observation is something that a researcher notices when investigating a topic connected to the unit of analysis. The many production techniques used by different industries might be the unit of observation in manufacturing research. In contrast, the specific equipment or parts utilized in these techniques could be the unit of analysis.

3.3 Target population and sampling:

The study's target population and sampling included students between the ages of 20 to 30 and above. We employed a number of resources, including Google, LinkedIn, and different personalized learning systems, to determine the overall population. For our investigation, convenient and random sampling was employed. A total of 120 sample sizes were collected.

3.4 Questionnaire Designing:

In order to create a trustworthy questionnaire for this study, the following steps were taken:

- We employed measurement items with validation for Sustainability Integration, Framework Development, SDG Awareness, CSR Initiatives, ESG Integration, and SDG Goals, from previously published, checked works. The items underwent modifications and adaptations to satisfy the study's criteria.
- We have steered clear of using long or repetitive questions or technical or specialist language.
- In order to prevent any difficulties or non-response from the respondents, the questionnaire was sent to language experts for proofreading, which included a review of grammatical errors and wording. Senior academics and researchers in educational institutions were consulted for instrument relevance and content clarity feedback.

3.5 Measurement scale:

The two primary iterations of the Likert scale that are widely applied in any research are the 5- and 7-point scales. We have used a 5-point scale for our study because it provides us with simplicity and clarity and may make it simpler to do fair and consistent evaluations. That is why a 5-point Likert scale was considered for this study. We gave the scaling from 1 – Strongly agree to 5– Strongly disagree.

3.6 Data Collection Process:

A Google form with the research objectives mentioned was circulated to various educational institutes and students. We sent a follow-up email to non-respondents. A total of 120 completed surveys were received.

4. Data Analysis

4.1 Data Analysis Technique: SmartPLS version 4 with PLS-SEM methodology was used for the survey investigation because it explores relationships among moderators and observed and unobserved variables. The assessment of hypotheses through structural models and measurement becomes possible through PLS-SEM due to its capability to handle both latent and observed variables against traditional analysis.

4.2 Analysis:

Figure 2: Structural Model

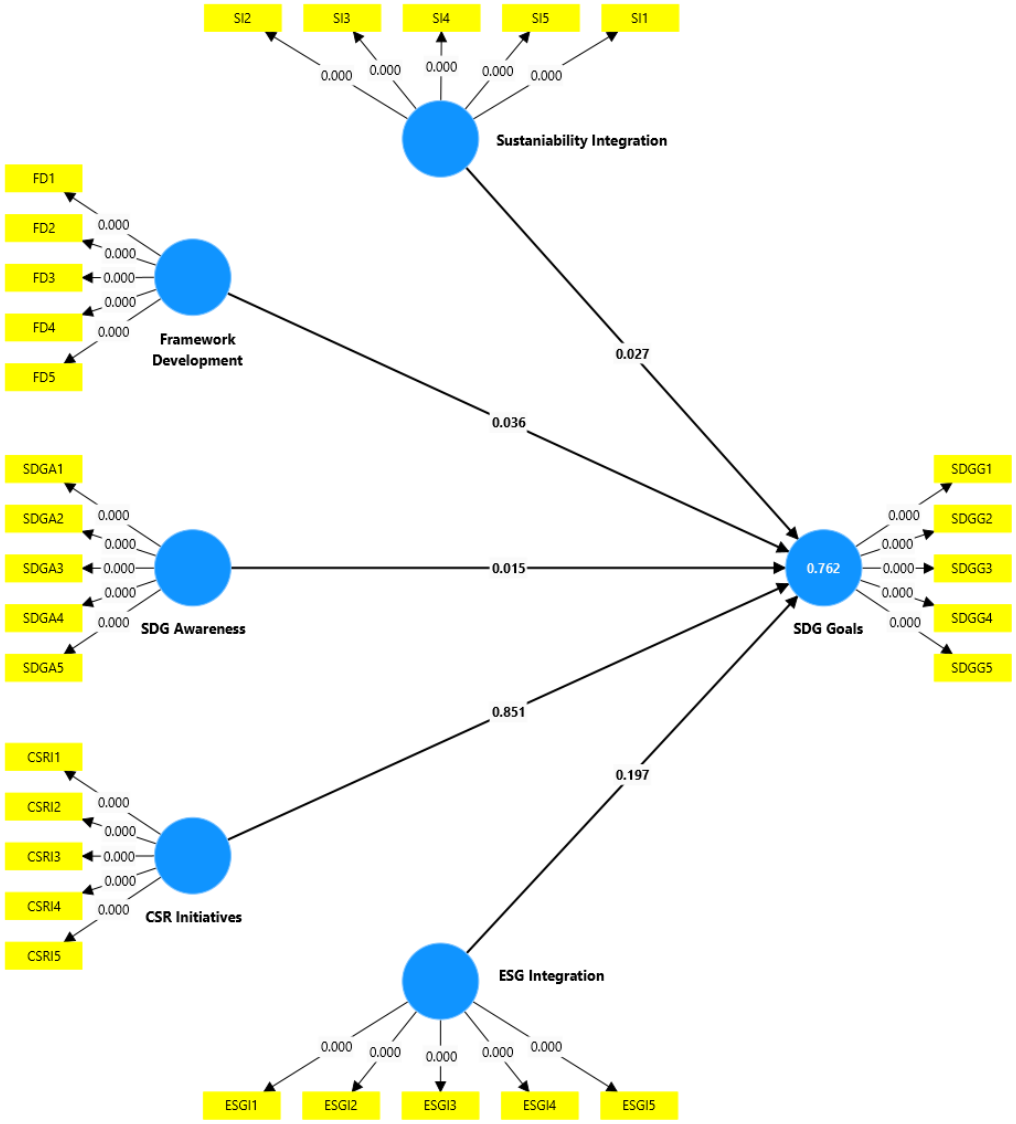

Figure 3: Measurement Model

Table 3: Socio-Demographic Table

Category	Sub-category	Frequency	Percentage (%)
Age	20 - 25	87	72.5
	25 - 30	29	24.16
	30 and above	4	3.33
Gender	Male	67	55.83
	Female	53	44.16
	Prefer not to say	0	0
	Others	0	0
Experience Level (Professionals)	Fresher	59	49.16
	Experienced	61	50.83
Total		120	100

Age Distribution: The statistical data reveals that age group participants between 20 to 25 make up 72.5% of the total respondents with 24.16% belonging to the 25–30 range and 3.33% being 30 years or older. The data presents 3.33% of participants who belong to the age range over thirty. Statistics show a high engagement level among young men and women who may represent new professionals and students pursuing their careers.

Gender Distribution: The investigation maintained a balanced gender ratio because 55.83% of survey participants were male while 44.16% belonged to the female group. The survey inclusively provided "Prefer not to say" and "Others" as optional answers but no one selected these options.

Experience Level: The survey participants are evenly divided with 49.16% being freshers while 50.83% belong to the experienced professional category. Diverse perspectives emerge when these two groups are combined because the survey includes both freshers and experienced professionals.

4.3 Data Analysis and Results:

Table 4: Outer Loadings

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
CSRI1 <- CSR Initiatives	0.772	0.765	0.049	15.895	0.000
CSRI2 <- CSR Initiatives	0.586	0.589	0.079	7.394	0.000
CSRI3 <- CSR Initiatives	0.660	0.661	0.075	8.859	0.000
CSRI4 <- CSR Initiatives	0.653	0.650	0.066	9.950	0.000
CSRI5 <- CSR Initiatives	0.702	0.690	0.087	8.104	0.000
ESGI1 <- ESG Integration	0.737	0.730	0.057	12.939	0.000
ESGI2 <- ESG Integration	0.717	0.717	0.060	11.924	0.000
ESGI3 <- ESG Integration	0.656	0.657	0.067	9.743	0.000
ESGI4 <- ESG Integration	0.569	0.567	0.088	6.498	0.000
ESGI5 <- ESG Integration	0.696	0.691	0.088	7.886	0.000
FD1 <- Framework_Development	0.446	0.444	0.107	4.156	0.000
FD2 <- Framework_Development	0.789	0.789	0.036	21.784	0.000
FD3 <- Framework_Development	0.693	0.694	0.061	11.290	0.000
FD4 <- Framework_Development	0.685	0.676	0.066	10.333	0.000
FD5 <- Framework_Development	0.763	0.759	0.054	14.194	0.000
SDGA1 <- SDG Awareness	0.429	0.435	0.084	5.139	0.000
SDGA2 <- SDG Awareness	0.711	0.706	0.068	10.459	0.000
SDGA3 <- SDG Awareness	0.847	0.841	0.044	19.156	0.000
SDGA4 <- SDG Awareness	0.795	0.792	0.047	16.935	0.000
SDGA5 <- SDG Awareness	0.810	0.804	0.046	17.753	0.000
SDGG1 <- SDG Goals	0.634	0.628	0.074	8.630	0.000
SDGG2 <- SDG Goals	0.805	0.807	0.037	22.011	0.000
SDGG3 <- SDG Goals	0.745	0.745	0.052	14.380	0.000
SDGG4 <- SDG Goals	0.680	0.683	0.050	13.570	0.000
SDGG5 <- SDG Goals	0.584	0.588	0.070	8.354	0.000
SI2 <- Sustaniability Integration	0.625	0.622	0.070	8.958	0.000
SI3 <- Sustaniability Integration	0.827	0.824	0.035	23.672	0.000
SI4 <- Sustaniability Integration	0.812	0.812	0.028	28.811	0.000
SI5 <- Sustaniability Integration	0.657	0.651	0.071	9.274	0.000
SI1 <- Sustaniability Integration	0.526	0.528	0.087	6.082	0.000

The table shows outer loadings for 30 different variables. The table shows each variable's original sample mean, sample mean, standard deviation, T statistics, and p values.

In PLS-SEM, T statistics and p values determine whether variables have a significant relationship to latent variables. Upon demonstrating significance ($p < 0.05$), every outer loading disproves the null hypothesis and validates the relationships. T statistics show the strength of the relationship and range from 4.156 to 28.811, indicating different degrees of association.

Overall, the table provides evidence that all variables are related to the latent variable. However, the strength of these relationships varies.

Table 5: Construct reliability and validity

Construct reliability and validity - Overview

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)
CSR Initiatives	0.703	0.700	0.808
ESG Integration	0.703	0.708	0.808
Framework_Development	0.705	0.731	0.812
SDG Awareness	0.771	0.806	0.848
SDG Goals	0.727	0.738	0.821
Sustaniability Integration	0.730	0.759	0.823

An evaluation of the model's construct validity and reliability is shown in the table. Interestingly, metrics like Cronbach's alpha, average variance extracted (AVE), composite reliability (rho_a), and composite reliability (rho_c) all exceed the generally accepted cutoff point of 0.5. This indicates strong internal consistency between the items measuring the same underlying construct and shows that the model measures the intended construct accurately. The findings demonstrate that the model has good validity together with reliability measures.

We can observe the following details regarding data in the table:

The Cronbach's alpha for all constructs is above 0.7, which is considered good.

The constructs show excellent Composite Reliability (rho_a) performance along with other acceptable criteria that exceed 0.7. The Composite Reliability (rho_c) exceeds 0.8 for every construct which demonstrates excellent measurement quality.

The model demonstrates good construct reliability and validity according to the information presented in the table.

Table 6: Path Coefficients

Path coefficients - Mean, STDEV, T values, p values

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
CSR Initiatives -> SDG Goals	-0.025	-0.032	0.134	0.188	0.851
ESG Integration -> SDG Goals	0.254	0.245	0.197	1.292	0.197
Framework_Development -> SDG Goals	0.240	0.220	0.115	2.093	0.036
SDG Awareness -> SDG Goals	0.284	0.290	0.116	2.441	0.015
Sustaniability Integration -> SDG Goals	0.230	0.258	0.104	2.212	0.027

This analysis looked at how several factors affected MBA Students Perception of Organizational Strategies Driving Sustainability Goals. Following is a summary of the main conclusions:

Supported Hypotheses:

- **H1:** Sustainable organizations are more likely to gain sustainable development goals because it embraces environmental and social change (p-value = 0.027).

- **H2:** Strengthening approaches of managing sustainable practices will help organizations to integrate better their activity with the framework of sustainable development goals (p-value = 0.036).

- **H3:** Increased level of awareness of the Sustainable Development Goals will help the aspiring managers to support organisational strategies towards these goals (p-value = 0.015).

Hypotheses Needing Further Investigation:

- **H4:** The CSR activities improve a firm's capacity to facilitate the realization of the sustainable development goals since it deals with handling the societal issues thereby undertaking inclusive development, but the evidence is not statistically significant (p-value = 0.851). More data or analysis might be needed for a conclusive answer.

- **H5:** When implemented, ESG factors bring about positive impacts during decision making, helping support the achievement of the Sustainable Development Goals, but the p-value (0.197) does not support the hypothesis. Further investigation is required.

Research findings examine important elements which influence MBA students' attitudes toward organizational approaches for sustainability achievement. Organizational success in gaining student support for these strategies depends on sustainable business integration that provides framework structures and global sustainability goal enlightenment. Business strategy effectiveness also relies on

corporate responsibility efforts and ESG alignment with established corporate responsibility initiatives and operational simplicity in integrating sustainability within current business frameworks. A closer examination must be done to gain full comprehension about how feasible and impactful each strategy will be in the long run because of its perceived potential.

Patterns and Insights:

1. **Sustainability Integration:** This serves as an essential component which creates positive reactions from prospective managerial candidates. The integration of sustainability throughout organizational business processes and corporate strategy decisions improves its industry acceptance and expertise recognition from future management professionals.
2. **Framework Development:** This is a process which establishes formal methods and organized sustainability models to implement the strategy creates more confidence about organizational dedication. Students find it simpler to understand sustainability strategy deployment because of well-defined frameworks.
3. **SDG Awareness:** Student attitudes towards sustainability improve strongly when they know more about the Sustainable Development Goals. Educational practices that provide clear information about SDGs' direct and indirect

influences lead students toward strengthened commitment with sustainability initiatives.

4. **CSR Initiatives:** This generates value however single-handedly Implementing them may fail to drive customer perception. Hungry customers need sustainability efforts that combine quantifiable sustainability results together with active business participation.
5. **ESG Integration:** This holds a fundamental position but require simple understandable formats to help students recognize their application in business problems. Complex ESG evaluation models deter students from both active participation and good assessments of program performance.

Main Goal: SDG Goals

Successful strategic approaches need to accomplish sustainable promotion and implement straightforward procedures and build structured awareness campaigns for maximum results. Organizations working to boost MBA students' sustainability perceptions need to base their strategies on actual corporate practice by creating sustainability as an embedded business requirement instead of separate external responsibilities.

5. Results and Discussion

The following section shows analytical results which demonstrate links to previous studies and support hypothesis confirmation while showing their implications for the examination of MBA students' views about organizational sustainability strategies. Organizations now focus strongly on sustainability within their strategy since they grasp the value of implementing business models congruent with SDGs. Research into how MBAs interpret organizational sustainability strategies matters because it allows organizations to shape their policy approach and successful implementation of such initiatives.

The investigation delivers understanding about how MBA students view established organizational sustainability approaches. Analysis results indicate students do value sustainability integration yet they recognize substantial differences between business implementation and managerial demands. Future managers rely on five critical strategies which include Sustainability Integration together with Framework Development and SDG Awareness as well as CSR Initiatives and ESG Integration to develop their sustainability mindset.

Research data indicate organizations should incorporate sustainability management into their structures since these tests resulted in significant outcomes (H1, H2, and H3) (Seva-Larrosa et al., 2023; Cole & Chicksen, 2018). MBA students prefer defined sustainability policies because they play essential roles in influencing corporate strategy as vital stakeholders (Freeman et al., 2018).

Statistical data failed to back CSR initiatives and ESG integration measures in H4 and H5 so stakeholders remain unsure about their effects. Businesses should improve their communication efforts regarding ESG initiatives and CSR activities according to (Williams et al., 2023 and Grainger-Brown & Malekpour 2019). Student awareness toward SDGs creates a significant impact on their support for corporate sustainable initiatives while supporting the need for sustainability education at academic institutions (Licandro et al., 2024).

Businesses need to develop sustainability strategies which match the expectations of future organizational management teams. Core business practices should include sustainability principles to complement improved communication about CSR and ESG initiatives which together create a gap-bridging approach toward developing sustainable workforce practices.

5.1 Hypothesis Testing and Results Interpretation:

- **Supported Hypotheses:**

H1: The adoption of environmental and social change by sustainable organizations leads to increased chances of achieving sustainable development

goals.

(p-value = 0.027, Supported)

Organizations which develop sustainable strategies find better success in reaching SDGs. The results match those presented in Seva-Larrosa et al. (2023) which showed that sustainable integration strengthens organizational performance and resilience toward sustainability milestone achievement. SDGs provide businesses with enhanced competitive positions as well as long-term sustainability based on the findings published by (Cole & Chicksen, 2018).

H2: Organizations that adopt stronger sustainable practice management outcomes will effectively unite their operations with sustainable development goals.

(p-value = 0.036, Supported)

Scientific studies prove that organizations which develop structured sustainability initiatives obtain superior performance in adopting the SDG framework. (Grainger-Brown & Malekpour, 2019) validate through their evidence that sustainability frameworks improve organizational accountability and Foroudi et al. (2024) indicate the significance of developing sustainability plans based on regional characteristics.

H3: Future managerial personnel who understand Sustainable Development Goals will help organizations by implementing strategies aimed at these goals. (p-value = 0.015, Supported)

SDG adoption progresses because raising awareness functions as an essential basis for this process. Workers who know more about sustainability principles create substantial growth in corporate support for SDG programs according to Licandro et al. (2024) and Singh et al. (2023). This highlights the importance of integrating sustainability education into corporate training programs to enhance employee engagement and commitment to SDG initiatives.

Hypotheses Requiring Further Investigation:

H4: The implementation of CSR activities enables businesses to better facilitate SDG realization because they handle social problems through inclusive development solutions.

(p-value = 0.851, Not Supported, Requires Further Data)

The research shows no conclusive statistical evidence that CSR benefits SDG realization as evaluated by Elmassri et al. (2024). The absence of concrete data indicates either that SDG-related CSR initiatives avoid objective matching or that measurement discrepancies create unclear outcomes when examined from the studied samples.

H5: ESG factors generate beneficial outcomes throughout decision-making processes that support organizations in achieving the Sustainable Development Goals.
(p-value = 0.197, Not Supported, Requires Further Investigation)

This study points out that although Wiliams et al. (2023) and (Botchway and Bradley, 2023) agree that ESG integration helps reach sustainable development goals (SDGs), the data reveals no statistically meaningful relationship between these factors. Insufficient application of practical ESG strategies in organizations and different perceptions of MBAs toward ESG success appear to explain these outcomes.

5.2 Discussion and Comparison with Existing Literature:

Among the validated findings (H1, H2, H3) sustainability integration proved together with structured management practices and enhanced awareness to be essential drivers for achieving SDGs. The findings regarding the two hypotheses (H4 and H5) for CSR initiatives and ESG integration need further evaluation because previous research shows these benefits yet the statistical results from this study fail to demonstrate direct causality.

Multiple factors were responsible for this mismatch in findings including:

1. **Differences in Implementation:** The documented value of ESG and CSR for sustainability frameworks becomes efficient only when these approaches are fully integrated across business implementation strategies.
2. **Sample Perception**: The limited contact that MBA students have with corporate ESG and CSR activities produces varying subjective interpretations regarding these initiatives.
3. **Measurement Challenges**: The assessment of ESG and CSR effects on SDG success necessitates extensive time-constrained research rather than conventional survey methods.

6. Implications

6.1 Theoretical Contribution:

Research expands current knowledge about organizational strategies and sustainability through student perspectives of sustainable goals among entrepreneurship students. Studies dedicated to corporate sustainability framework deployment have received primary attention until researchers bridged academic insights to actual business practices by analyzing students' perspectives. The study establishes new views for future business leaders regarding sustainability methods

and shows why educational approaches shape managerial mental models. Stakeholder Theory gains dynamic dimensions through this theory because it includes future manager perspectives (Freeman et al., 2018) to discuss sustainable business practices.

The research adds value to studies regarding Sustainable Development Goal Integration through its discovery of essential business approaches which appeal to upcoming managers. The academic understanding of early career sustainability perceptions grows through analysis of the essential areas of Sustainability Integration, Framework Development, SDG Awareness, CSR Initiatives and ESG Integration. The analysis creates a need to pair corporate sustainability objectives against what emerging business leaders expect because current SDG-focused academic research does not address this connection (Seva-Larrosa et al., 2023).

The presented research extends previous findings about Stakeholder Theory because it promotes consideration of multiple business stakeholders during decision-making (Freeman et al., 2018). The research presented in this study supports a stakeholder assessment which includes MBA students since they will become future corporate decision-makers. Companies achieve long-term sustainable practice commitment by matching their sustainability programs to what future managers expect (Grainger-Brown & Malekpour, 2019).

Sustainability education integrated through business management principles enables institutions to train leaders who acknowledge environmental challenges alongside

acquiring implementation methods for effective approaches. The developed theory system strengthens academic efforts to establish sustainability throughout professional training and higher education thereby advancing academic institutions in their sustainability leadership role worldwide (Licandro et al., 2024).

6.2 Managerial Implications:

Managers should view these study results as proof that companies require sustainability education inclusion for their corporate training and leadership development programs. Business organizations should provide MBA graduates and emerging managers with sustainable knowledge and implementation skills that deliver effective sustainability projects. Organizations can develop a workforce capable of creating sustainable solutions through strategic execution when they introduce sustainability principles to all stages of employee development and training (Eccles & Klimenko, 2019). Sustaining educational programs for companies generates sustained usefulness by meeting regulatory standards better and optimizing efficiency and affirming stakeholder belief.

Businesses need to develop their Environmental Social and Governance (ESG) frameworks better by implementing thorough data-based sustainability approaches. Businesses need to establish proper systems that combine structured ESG measurement and reporting as they advance their sustainability practice. Through ESG transparency businesses can lower the possibility of greenwashing while

ensuring all sustainability statements have solid verification (Ioannou & Serafeim, 2011). Through ESG transparency businesses can lower the possibility of greenwashing while ensuring all sustainability statements have solid verification (Ioannou & Serafeim, 2011).

Businesses need to turn sustainability into a permanent operational aspect which integrates into every core business process rather than treating it as an isolated function. Several businesses limit sustainability responsibilities to isolated departments whose main task involves compliance work and report generation thus creating execution difficulties. Organizations need to embed sustainability throughout their product development as well as supply chain management financial planning and corporate governance processes (Elkington, 2004). Businesses that integrate sustainability objectives into their main lines of operation achieve higher market performance and competitive advantage along with stronger customer trust (Porter & Kramer, 2011). Businesses that integrate sustainability objectives into their main lines of operation achieve higher market performance and competitive advantage along with stronger customer trust (Porter & Kramer, 2011).

7. Conclusion:

The integration of quantitative data analysis supported by theoretical constructs confirms how organizations achieve SDG-based integration through the combination of sustainability awareness and strategic management methods.

Corporate Social Responsibility (CSR) and Environmental, Social, and Governance (ESG) initiatives demonstrate uncertain outcomes according to the study while future research must evaluate their prolonged effect on business achievement together with stakeholder relationships (Carroll, 2016).

Organizational success in sustainability demands widespread integration of environment-friendly practices starting from education to leadership development and defined policy systems. Active sustainability integration into corporate culture and strategic decision-making leads businesses to fulfill regulatory standards better along with strengthening stakeholder relationships and optimizing operational output (Montiel & Delgado-Ceballos, 2014). The accomplishment of sustainability goals needs organizations to develop strong training initiatives together with effective accountability standards and executive backing of sustainability targets.

The implementation of digital technologies in sustainability reporting and carbon footprint monitoring and supply chain transparency functionality allows companies to achieve better sustainability target performance Schaltegger et al. (2016). The study of how emerging technologies modify managerial choices as well as organizational policies generates data that benefits educational research together with business practices.

Different industries follow separate paths by establishing their priority focus either on carbon reduction or ethical sourcing and waste management or social equity initiatives. Comparing sustainability approaches between different sectors will help

organizations create improved best practices which lead to specific frameworks for achieving SDG targets. Research expansion in sustainability enables authorities alongside organizations to create more efficient strategies which produce enduring environmental and social effects.

8. Limitations and Future Research Directions:

8.1 Limitations:

The study is limited by several factors. Firstly, its geographical scope is restricted to a specific boundary, preventing the inclusion of worldwide observations. Secondly, the reliance on self-reported data introduces the risk of personal reporting biases, as respondents may lack direct experience with the researched topic. The research fails to deliver useful information about sustainability challenges that differ between various industries. The results demonstrate statistical validity but the restricted sample size weakens the overall reliability of the study until researchers conduct an analysis with a bigger sample population. The analysis lacks data from multiple time periods that would enable monitoring of how sustainability perceptions evolve throughout those periods.

8.2 Future Research Directions:

Multiple essential components from the research serve to improve knowledge regarding sustainability perceptions. The research adopts comparative regional analysis to understand sustainability views between countries which leads to identifying regional-specific differences. The research examines strategic sustainability factors within distinct industrial sectors through evaluations of finance, manufacturing and healthcare industries. Qualitative interviews combined with different research approaches provide managers enhanced understanding about their sustainability-related knowledge and opinions. The research follows MBA students over time to observe their evolving sustainable perception development from the point of graduation and multiple years afterward. This research describes how digital transformation and artificial intelligence improve sustainability practices through evaluations of their organizational applications.

The paper expands research by suggesting a future direction for studies while demonstrating awareness of study boundaries through the identification of these limitations and proposed research directions. Our research provides an expanded and scholarly overview of human actions in the field.

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An Exploratory Research on ESG Strategies, Green Taxonomy, and SDGs: Pathways to Sustainable Development

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Abstract

ESG strategies piece an imperative role in combating climate change by prioritizing low-carbon technologies and nature-based solutions. While challenges remain, continued innovation and regulatory alignment can enhance their effectiveness in promoting a low-carbon, sustainable economy. Understanding these frameworks' interconnections is essential for policymakers, investors, and corporate leaders committed to long-term sustainability and climate resilience.

ESG strategies comprise corporate policies and practices leading to enhance environmental performance, governance standards and social responsibility. This

research explored how ESG strategies support climate action and environmental stewardship, aligning with select and relevant SDGs. Broadly speaking, firms adopt ESG strategies through sustainability reporting, stakeholder engagement, and regulatory compliance.

This study had put particular emphasis on Climate Action (SDG 13) which is directed towards integration of climate change actions into national policies, planning and strategies. It also talks about improving awareness and education on climate change mitigation to name few.

This research paper on ESG Taxonomy in India focused on evaluating the adoption, implementation, and impact of ESG taxonomy within the Indian context. The paper would address key aspects such as the regulatory framework, challenges, opportunities, and the financial sector's involvement in integrating ESG criteria. Green Taxonomy provides standardized criteria for sustainable investments, while SDGs offer a blueprint for global sustainability efforts. Understanding the synergies and challenges of these frameworks is crucial for fostering sustainable economic growth and mitigating climate change. This study also analyses the evolution of ESG reporting & taxonomy eco-system, the role of the Indian government and financial institutions in shaping ESG standards, and the practical application of ESG criteria by corporations.

1. Introduction

If one has to think about a term which encompasses almost all the aspects of business and its direct as well as indirect elements, Environmental, Social, and Governance (ESG) will be on the top of the list by any standards. ESG is an umbrella term covering a broader set of guidelines and standards used to gauge an organization's environmental and societal influence. Although most of the times it is referred in the context of business more specifically with finance or investment part of it, but in real terms it is applicable to almost all the stakeholders including employees, shareholders, customers and most important the society & environment.

The term "ESG" has grown in popularity in past few decades only and is often mentioned in the same conversations as sustainable development and corporate social responsibility (CSR). Whereas CSR function and sustainability are more on side of philosophies or end goals, ESG is more specific, encompassing the statistics, data, facts and metrics needed to backing decision-making for companies and investors for a sustainable growth for all the stakeholders.

Environmental, Social, and Governance (ESG) strategies have become integral to corporate decision-making, influencing its strategic direction, overall financial performance, regulatory compliance, and sustainability initiatives. Green Taxonomy on other hand, is a classification system that defines sustainable economic activities based on environmental impact. It helps align financial flows with climate and

sustainability goals by setting science-based criteria for investments. By promoting transparency and reducing greenwashing, Green Taxonomy supports climate action, biodiversity protection, and sustainable resource management. Green Taxonomy provides a classification system that aligns financial flows with sustainable objectives, ensuring investment in environmentally friendly activities. The Sustainable Development Goals (SDGs) propose a global framework for attending key sustainability challenges.

Despite of ESG being an important universal business term, the definition, its reporting standards and metrics have yet to receive a common global understanding and acceptance. The debate is more or less centred towards restricting the concept to fewer words and interpretation but will such a common set of interpretation ever evolve is the biggest question of the century for all the subject matter experts in this domain.

Considerable progress has been made for sure till date, but this requires lot more efforts in this direction. Political and social powers are trying to reach on aggregable standards to facilitate the version or agenda of politicians but the middle way to is a far distant dream looking into the magnitude of the concepts and its application. The emergence of detailed criteria and rules covering one side of the segment will make it more cumbersome to mitigate the other side of the segment.

Green taxonomies, which offer a standardized description of green assets, are one example of the policy tools being introduced in the rapidly changing sustainable finance markets. These resources are intended to boost funding for environmentally friendly projects, stop greenwashing, and aid in improving knowledge of the scope of climate hazards that different financial sector intermediaries confront. Despite their benefits, ESG strategies, Green Taxonomy, and SDGs face challenges like data standardization, regulatory fragmentation, greenwashing risks and climate finance gaps to name few. Greenwashing is a form of a deceptive practice where companies falsely claim that they are environmentally friendly to attract consumers which are conscious and sensitive towards environment. It involves exaggerating or/and misrepresenting sustainability specific efforts through misleading labels, ambiguous terms, or selective disclosures. Common tactics used by such firms include using green imagery, highlighting minor eco-friendly actions while intentionally ignoring significant environmental harm caused by them, and making unverified environmental claims. Greenwashing can mislead and misguide consumers into believing a product or company is more sustainable than it actually is in reality, resulting in diverting attention from real environmental issues.

Taking into consideration the stage at which India is standing right now in the global context and the pace at which it is rising to become an economic superpower, it is quite relevant to ask if the current approach sufficient for India for climate transition by 2070 with an estimated investment of around US $10.1 trillion? Through a

thorough analysis of all the elements of green taxonomy, this paper examines the existing ESG & Green Taxonomy framework, offering recommendations for improving the application as well as implementation of mentioned areas to foster long-term sustainable growth.

2. Literature Review

ESG, by all means includes corporate governance within its scope but in terms of aligning its overall strategies, ESG has got much wider scope in terms of alignment with evolving business models in current era. In the advent of diverse needs of stakeholders trying to access information using development technology, ESG practices have become more critical. This situation is due to the fact that such practices are an approach to corporate governance, indicating that companies act delicate and responsible for stakeholders. (Atasel & Güneysu, 2023).

In the era of ever evolving business scenarios, ESG practices plays crucial role for organizations to achieve an upper hand from its competitors and focus on sustainability of its operations without compromising the core values. This situation also applies to stakeholder groups with which companies have interactions: for example, investors expect the companies they invest in to be proactive on ESG

policies and practices. Only then can we generate good public image of the company (Legal, 2023).

Researchers and practitioners are investigating how environmental, social, and governance (ESG) strategies along with regulatory frameworks like green taxonomy, and the Sustainable Development Goals (SDGs) of the UN interact to promote sustainable development because of the growing emphasis on sustainability around the world. These three aspects have become crucial routes to more resilient and sustainable economies as companies, investors, and legislators look to reduce risks and generate long-term value (United Nations, 2015; Sachs, 2015).

ESG Strategies

ESG strategies have evolved from a set of voluntary corporate practices to a critical element in risk management and investment decision-making. Strong ESG performance was linked to better business reputation, cost savings, and risk mitigation, according to early research (Eccles et al., 2014). Strong ESG practices are frequently associated with reduced risk profiles and greater financial performance, according to later empirical studies, such as the meta-analysis (Friede et al., 2015). These results highlight the fact that incorporating ESG factors into business strategy is advantageous for the company's competitiveness as well as an ethical matter.

Green Taxonomy

A methodical approach for categorising economic activities that support environmental goals is the green taxonomy. This framework was started by regulatory organisations, most notably the European Commission (2020), with the goal of making it clearer and more consistent what makes an investment "green." Green taxonomy helps investors and financial organisations find and direct funds towards initiatives that are in line with environmental objectives by establishing clear sustainability standards. As a result, the taxonomy facilitates the wider use of ESG concepts in corporate finance and investing.

SDGs and Sustainable Development

A worldwide roadmap for attaining sustainable development by 2030 is provided by the Sustainable Development Goals, which were established by the UN in 2015. These objectives cover a wide range of topics, from education and poverty alleviation to climate action and sustainable cities, all of which are strongly related to the fundamental principles of ESG and green taxonomy. Integrating SDG targets into public policy frameworks and corporate plans can promote systemic change and guarantee that sustainability initiatives result in observable socio-economic benefits (Sachs, 2015).

Interlinkages and Convergence

According to recent studies, a comprehensive approach to sustainable development can be achieved by combining ESG strategies, green taxonomy, and SDGs. Businesses can more successfully quantify and convey their contributions to sustainable development when ESG practices are in line with SDG aims (Kotsantonis et al., 2016). In the meantime, openness and accountability in sustainability reporting are supported by the clear, standardised classification system that green taxonomy offers (Dorfleitner et al., 2017). These interlinking frameworks helps to establish a collaborative way to link monetary and non-monetary performance to more general environmental and social results.

Literature Gap: ESGs and SDGs factors are becoming increasingly important in business plans and investments, according to recent study. An ESG-SDG mapping methodology for emerging markets is being put forth (Markopoulos & Ramonda, 2022), stressing on the importance of striking a balance between sustainability and economic growth. (Sciarelli et al., 2021) investigate how sustainable finance, and development might be supported by incorporating ESG criteria into socially conscious investment strategies. (Siddhartha, 2024) investigates how ESG considerations affect mergers and acquisitions, pointing to their ability to increase corporate reputation and create value. Together, these studies show how ESG and SDGs are becoming more and more important in influencing corporate strategies, investment choices, and business practices. They also show how financial success and sustainable development goals can work in tandem. Studies have been done in past on various aspects of ESG, SDGs, climate action and sustainability but in

exploring these areas in isolation. The study is to explore the interconnectedness of ESG strategies with SDGs and how can they be beneficial in attaining sustainable development.

The literature implies that ESG strategies, green taxonomy, and SDGs are interrelated frameworks that offer diverse yet complementary pathways to sustainable development. While ESG strategies underline the role of corporate behaviour in mitigating environmental and social risks, green taxonomy offers a structured approach to defining sustainable investments, and the SDGs offer a comprehensive agenda for global development. When combined, they offer a diverse strategy for attaining sustainability, but further study is needed to solve current issues and maximise their compatibility.

3. Research Methodology

This study is a conceptual study falling under the exploratory research design. The survey of concerning literature is done through various research papers, reports and other literature available on the matter. This study's methodology provides a thorough conceptual framework for investigating the areas in which SDGs, green taxonomy, and ESG strategies intersect as avenues for sustainable development. The study attempts to give a thorough conceptual model that not only clarifies existing

practices but also directs future corporate strategies and policies by combining various sources and theoretical frameworks. This paradigm lays the groundwork for future empirical studies that might improve and test the suggested links.

The conceptual study is guided by several key research questions:

- What are the core components and theoretical footings of ESG strategies, green taxonomy, and the SDGs?
- What interactions and overlaps exist between these frameworks to support sustainable development?
- What are the potential synergies and challenges among these frameworks in the context of global sustainability?
- How can a cohesive conceptual framework be created to direct corporate strategy and future policy in the direction of sustainable development?

Given the conceptual nature of the study, secondary sources of data collection has been used including academic journals, policy & regulatory documents, industry reports, conference proceedings and working papers. The review synthesizes key findings from scholarly articles, policy documents, and authoritative reports. The different concepts related to the topic have been studied and analysed thoroughly and the conceptual base has been presented in the concise manner to through light on the need of the matter. IMRD (Introduction, methodology, result and discussion)

approach has been followed. The data analysis and discussion have been divided into segments for clarity.

4. Data Analysis & Discussion

The study employed content and thematic analysis. A qualitative content analysis approach is employed to:

- **Extract Key Themes:** Identify recurring themes, dimensions, and trends in the literature relating to ESG performance, regulatory frameworks, and sustainable development.
- **Categorize Findings:** Organize themes into clusters (e.g., environmental impact, social responsibility, governance mechanisms) that inform the conceptual framework.
- **Interpret Relationships**: Analyse how the identified themes interact and what implications they have for sustainable development pathways.

This part of the study has been divided into below mentioned parts relating to different objectives of the study.

- **Taxonomy as Means of Standardization**
- **Green taxonomy & Its Role in ESG and Sustainable Development**

- **Taxonomy & Market Integrity**
- **ESG as a Strategic Tool**
- **SDG 13 – Integrating Climate Change**
- **Synergies & Challenges**

Taxonomy as Means of Standardization

Importance of standardization and reliable data: At the time we are talking about uniformity and standards, Taxonomy cannot to left untouched in this debate. Going by the definitions available in public domain, “Taxonomy is the science of naming, describing, and classifying organisms, or more generally, the classification of things or concepts. The word comes from the Ancient Greek word taxis meaning "arrangement" and - nomia meaning "method". Broadly speaking it can be sort of classification or sort of scientific way of arranging thing in groups. It is believed that in ESG domain, Taxonomies are among the latest policy tool to join the movement to fast-track the business transition around the world. They are essentially policy documents in the form of frameworks or guidelines that set decision criteria for economic activities or investments that can be classified as "sustainable" or "green”. At the stage of defining standards, one must form a balance between fine details and some amount of flexibility in handling the associated aspects. At one hand regulators will try and enforce standardization and transparency, industry on other hand would emphasise on minimum amount of complication so as to ensure smooth capital flow in the system together with long-term business sustainability. The transition from

traditional to renewable form of business practices, though will have to be faster and streamlined.

Taxonomy places a system of safeguard and provides a criterion for screening between green and other non-green activities. It also provides a common and standardised framework across globe for ease of measurement and finally it paves way for better transparency amongst all the stakeholders for ensuring a level playing field for all without compromising the environmental aspect in investments and sustainability in business operations. Considering the global unease on availability of numerous uncommon standards, experts on sustainability are trying to bring in consistent set of standards for corporate reporting throughout nations.

Various entities including The IFRS Foundation Trustees, the International Sustainability Standards Board (ISSB), Global Reporting Initiative (GRI), Carbon Disclosure Project (CPD), Climate Disclosure Standards Board (CDSB), and the Sustainability Accounting Standards Board (SASB), are working determinedly for finalizing globally suitable common standard of reporting. The standards will be both financial as well as non-financial but will be related to climate related factors for sure.

The impact that businesses have on the ecosystem around them, whether on a global scale or within their local communities, is becoming very clear. Whereas, the issues

related to ESG like climate change, human rights, equity – inclusivity and governance are of greater worry for global economies. Therefore, integrating sustainability into business is a top priority for both managers and invertors in today's environmentally conscious business eco-system.

Since stock markets have historically reflected public opinion, investors have refocused their asset management strategies to include a variety of ESG considerations in addition to financial success. Institutional investors are examining companies more closely than ever before in an effort to match their investing strategies with ESG considerations.

Green Taxonomy & Its Role in ESG and Sustainable Development

A classification scheme known as "green taxonomy" identifies environmentally sustainable practices and directs funding toward green initiatives. Because it encourages responsible finance, lessens greenwashing, and increases transparency, it is essential to sustainable development. Businesses and policymakers can better align with climate goals like carbon neutrality and biodiversity protection by creating explicit criteria for green investments. By making well-informed choices, investors may guarantee that funds go to initiatives that actually promote sustainability. Additionally, green taxonomy promotes innovation in green infrastructure, renewable energy, and the circular economy while making regulatory

compliance easier. In the end, it speeds up the shift to a robust, low-carbon global economy.

Taking the discussion back to Taxonomy, although taxonomies should ideally be based on published data, they are not always a tool for enforcing disclosure rules. An effective evaluation of how well an asset meets the requirements outlined in a taxonomy requires the disclosure of non-financial facts apart from other factors. This data is then used and maybe processed by taxonomies to categorize an asset based on its sustainability advantages. Naturally, well-designed taxonomies will benefit investor needs and other sustainability-related policies. For example, they can be used to help define non-financial disclosure obligations. However, giving investors an upfront understanding of the non-financial advantages of a particular asset is their main goal.

On the other hand, institutional investors and any other financial organizations need to access the relevant financial information of companies under investment to determine the ESG exposures of their investments. In lack of such compulsory and consistent reporting, definitions and metrices, it is difficult for organizations to obtain the precise data they need. Accuracy and reliability of the analysed data also depends upon the credentials of the available data for interpretation.

Taxonomy and Market Integrity

Long-term investor's interest in assets that are assigned a taxonomy-based label ultimately determines how well taxonomies contribute to sustainability goals. In addition to boosting investor interest, well-crafted taxonomies can also improve market transparency by guaranteeing investors that their money is successfully advancing specified sustainability objectives.

Therefore, well-designed taxonomies protect market integrity by making sure that investors can easily identify assets that are unable to provide the sustainability advantages needed for the label. In turn, market integrity encourages less sustainable companies to perform better and helps maintain longer-term investor interest in sustainable financing markets.

The term "taxonomy for climate finance" refers to uniform rules and policies that educate businesses and investors about the climate catastrophe and the benefits of making investments in environmental preservation. Taxonomy in finance, which has its roots in biology, where it is used to categorize species, establishes precise standards for green investing.

According to the International Finance Corporation (IFC), the fundamental question that need to be answered is what 'green' means. The absence of this is creating diverse interpretations of constitute of green and also creating confusion in the minds of investors. A detailed list of business and economic activities aligned with climate

goals has been provided by green taxonomies or climate finance taxonomies. This offers a structured methodology to sustainable investments.

Adopting a comprehensive strategy that takes into account the behavioural implications of the economic, social, ecological, policy, and regulatory settings is the only way to fully comprehend how sustainability affects the real estate investment landscape.

An exhaustive cross-country analysis was performed by applying ESG regulatory frameworks for selected developed and developing countries. Comprehensive review of the literature suggested that standalone ESG disclosures, which may be voluntary or mandatory, could not only be responsible factors for uplifting the country's overall ESG levels. The effectiveness of these measures will remain absent unless and until these initiatives go to masses and the public at large. The study further suggests that to give upper hand to ESG practices, integrated reporting practices and sustainability reporting is essential.

Addressal of information asymmetry concerns and construction of robust corporate operations and reporting procedures, demand national environmental assurance. This will also help to establish a new sustainable practice that must be implemented for both developed and emerging markets. Apart from other benefits, this will ensure synchronised efforts at all ends.

The regulators should try to devise policies in conjunction with Triple 'C' namely convenient, comparable and credibility and should have the flexibility required to handle black swan events like Covid-19. This is a unique method of classification, and can be limited to the scenario of Covid but otherwise too can be useful. It is further suggested that the policies and disclosure should be devised to address the information asymmetry problem which mainly exists when regulations are non-mandatory. This again stands true for the fact that unless the regulatory framework is streamlined, implementation of such practices will always be difficult and burdensome.

The Organisation for Economic Co-operation and Development (OECD) has done extensive study in the discipline of ESG and corporate governance. They have done a comprehensive study on the needs of capital markets and the type of funds available as well as suitable in the market with reference to sustainability and climate requirements. The study states, "Even though capital markets offer heterogeneous products, as all types of bonds matching different needs can be found, the issuance of specific types of debt instruments is largely driven by investor demand, that in turn reflects current market preferences. That is why, in the last decade, investment instruments designed to help the transition to sustainable development and climate mitigation and adaptation have seen developments in terms of both volume and structure (IOSCO, 2020[2])." Capital markets have always been a major source of

funding by ensuring they match investor needs and create sustained value for all the stakeholders.

The United Nations Sustainable Development Goals (SDGs), the Paris Agreement, the Glasgow Financial Alliance for Net Zero (GFANZ), and the national and supranational frameworks for climate change mitigation and adaptation and social inclusion are such forums and actions at the global level that reflects the need of alignment of capital markets with the political, social and environmental landscape. Another global giant in consulting, McKinsey, has done tremendous work in the ESG eco-system. One of its reports states that, "About 85% of the chief investment officers we surveyed state that ESG is an important factor in their investment decisions. 60% of respondents review their overall portfolio for ESG considerations, and about 80 % assess individual company positions in the context of how ESG affects forecasted cash flows." These are interesting and sizable numbers to be counted and considered. The report further states, "Strikingly, a significant majority are prepared to pay a premium for companies that show a clear link between their ESG efforts and financial performance." This is indeed a remarkable number in terms of the acceptance of the investors of the funds and organizations which resonate concern of climate and society in their portfolio matrix.

ESG as a Strategic Tool

ESG considerations are becoming crucial strategic instruments for companies hoping to succeed in the long run. ESG frameworks assist businesses in reducing risks, improving the reputation of their brands, and luring ethical investors. Organizations increase operational effectiveness, adhere to regulations, and cultivate stakeholder trust by incorporating ESG into decision-making. Competitive advantages including employee happiness, consumer loyalty, and access to sustainable funding are brought about by strong ESG performance. Businesses that put an emphasis on ESG are better equipped to handle global issues like social inequality and climate change. In the end, ESG acts as a guide for lucrative, moral, and resilient company expansion in a world that is changing quickly.

ESG and Sustainable Finance Taxonomy in India: As mentioned above, one of the commendable initiatives in the area of ESG by the Government of India is the introduction of climate finance taxonomy in the 2024-25 budget. This will definitely revolutionize the sustainable landscape in India together with giving it much needed regulatory push to the financial markets. By establishing clear guidelines and framework, ESG taxonomy will not only ensure smooth flow of activities in the capital market but will also ensure projects which will be ESG compliant and increase participation of responsible investment stakeholders and ultimately promote responsible and climate centric/carbon neutral economy.

In this journey, regulators will have to be cautious about their approach and be mindful of certain points:

- *Unambiguous and transparent mechanism* - Clear and transparent approach towards the green economy is the need of the hour. In an economy like India, the dependence of the natural environment for livelihood is humongous. Majority of the government schemes are for upliftment of the lower strata of the society. Organizations will have to be clear in terms of the approach towards government centric schemes or climate centric goals.
- *Stakeholder engagement* – The approach to a green economy has to be extended to all the stakeholders. Their participation and a common understanding to this effect is non-negotiable for the success of the initiative.
- *Localization* – One side definitely does not fit all, especially in this case. Global is the new local as they say and that is why Indian think tanks should not miss the local touch in its way to align our approach to match the global standard. India has got its different political, economic and social set-up and it may definitely not match with that of western or eastern economies of the world. Some amount of customization will have to be made for the acceptance of the masses at the grassroot level without compromising the global spirit.
- *Strong regulatory approach* – India is known for its strong regulatory mechanism. Institutions like RBI, SEBI, IRDA etc are backbone on our ecosystem and perhaps that is one of the most important factors in the manner in which Indian economy, despite been considered as a developing nation,

could withstand the impact of global turmoil like financial crisis, covid-19 etc in a better manner than rest of the world.

Solar, wind, and hydropower are examples of renewable energy sources in which the Indian government has made significant investments. This has made it possible for the nation to transition away from costly fossil fuels and march toward sustainable energy. Furthermore, it is trying to raise the amount of forest cover and has taken action to prevent deforestation and degradation of its forests.

To assist companies in making the shift to green technologies and become more sustainable, the government has also instituted a number of subsidies and incentives. This involves, amongst other things, the Low Carbon Technologies Fund, the Patents Facilitation Fund, and the National Adaptation Fund on Climate Change.

ESG Disclosures by Listed Entities, ESG Ratings by ESG Rating Providers (ERP), ESG Investing by Mutual Funds/Asset Management Companies (AMCs) are some of the initiatives by the Government of India under its ESG framework which has gathered momentum in last one odd decade. The Ministry of Corporate Affairs (MCA) National Voluntary Guidelines on Social, Environmental and Economic Responsibilities of Businesses was later on adopted (and mandated) by the SEBI through the introduction of Business Responsibility Reports for top 100 listed

companies. Later on, the BRR requirement was extended to top 1000 listed companies by virtue of market capitalization.

The ESG committee of SEBI has also recommended a list of 15 Indianized ESG parameters in order to bring more consistency and assist ESG Rating Providers in adopting a common approach for rating. The broad parameters of rating are based on the 3 pillars of ESG. Waste management, biodiversity, CSR, DEI, compliance, related party transactions etc. are few key parameters which are followed by rating agencies for ensuring uniformity in its evaluation.

SDG 13 – Integrating Climate Change

Climate Action-SDG 13 aims on critical measures to fight climate change and its impacts. Because ecosystems, economies, and human well-being are all seriously threatened by climate change, it is crucial to include climate resilience into planning, policies, and practices in all spheres of society.

Governments, corporations, and communities must implement climate adaptation and mitigation measures in order to meet SDG 13. This includes lowering greenhouse gas emissions, funding renewable energy, encouraging environmentally friendly land use, and improving preparedness for emergencies. Promoting public involvement and behavioural change requires a strong emphasis on climate education and awareness. Resource sharing, technological transfer, and financial

help for vulnerable countries are made possible by strengthening international collaboration, such as that which has been achieved under the Paris Agreement. By implementing green technology, increasing energy efficiency, and pledging to meet net-zero carbon targets, corporations can support SDG 13. When it comes to allocating funds to sustainable projects, financial institutions are also crucial.

Long-term sustainability is ensured by incorporating climate change into development and economic policies. By working together, we can preserve biodiversity, create societies that are robust to climate change, and save the earth for coming generations. A sustainable, just, and prosperous world depends on achieving SDG 13.

Synergies & Challenges

Synergy in ESG Implementation in Organizations: ESG concepts work best when applied collectively as opposed to separately. A comprehensive ESG strategy makes sure that corporate governance, social responsibility, and environmental sustainability all support one another, which promotes value generation and long-term company resilience.

For example, by lowering pollution (social), a company that invests in renewable energy (environmental) can improve employee well-being while bolstering ethical leadership and regulatory compliance (governance). In a similar vein, social

diversity and inclusion programs can enhance corporate governance frameworks and decision-making procedures, encouraging creativity and long-term expansion.

Synergistic ESG integration improves stakeholder trust, risk management, and operational efficiency. Cross-functional cooperation between leadership, HR, compliance, and sustainability teams guarantees that ESG goals complement corporate objectives. ESG synergy is further supported by technology and data analytics, which monitor developments, spot hazards, and facilitate well-informed decision-making.

Businesses that successfully incorporate ESG factors gain regulatory advantages, enhanced investor confidence, and better brand recognition. Businesses can meet legal obligations and promote sustainable value creation by integrating ESG into their corporate culture. In the end, a synergistic ESG approach establishes businesses as accountable leaders who secure long-term financial success while making a favourable effect on the environment and humanity.

Challenges in ESG Implementation: While the growth of ESG investing is undisputable, the process of implementing ESG practices within organizations, investment portfolios, and financial markets faces several noteworthy challenges. These obstacles range from data gaps to inconsistent regulations and the complexities of measuring the actual impact. Understanding and addressing these

challenges is crucial for investors, businesses, and legislators aiming to incorporate sustainability and ethical practices into overall decision-making. This last segment deals with some specific challenges in the said field.

- *Lack of Standardized System of Measurement and Reporting* - One of the most significant hurdles in ESG implementation is the absence of universally accepted standards for measuring and reporting ESG performance. Different organizations and countries have adopted varying frameworks and criteria for ESG reporting, which makes it tough to compare data among firms and sectors. Inconsistent Metrics, Data Quality and Transparency, Emerging Standards are some of the key issues in this implementation. Although initiatives like the Global Reporting Initiative (GRI), Sustainability Accounting Standards Board (SASB), and the Task Force on Climate-related Financial Disclosures (TCFD) are gaining attraction, there is no universally agreed-upon framework for ESG metrics. This inconsistency can create confusion and hinder effective implementation of ESG strategies.
- *Data Availability and Reliability* - Even with a growing focus on ESG data, obtaining reliable and comprehensive information remains a significant challenge. Many companies still lack the infrastructure to collect, analyse, and disclose ESG-related data effectively. Gaps in the data makes it difficult for investors to evaluate risks and opportunities accurately and due to lack of third-

party verification investors cannot always trust the data they receive, which can undermine the integrity of ESG investments.

- *Greenwashing* - "Greenwashing" refers to the practice of companies or funds misleading investors about their ESG performance or the sustainability of their products and services. This can happen when companies exaggerate their environmental or social initiatives without making meaningful changes or when marketing claims about sustainability are not substantiated by actual practices. Some companies may highlight their 'green' or 'social' efforts in marketing or ESG reports, even if their overall operations do not align with these claims thereby misleading investors. While regulators are starting to address greenwashing, the lack of stringent enforcement and clear definitions can make it easy for companies to make unsupported claims about their ESG credentials.
- *Integration into Investment Processes* - Incorporating ESG factors into investing approaches, particularly in traditional finance sectors, can be challenging. Many investors still prioritize short-term financial returns and may not see the immediate value of incorporating ESG considerations.
- *Lack of ESG Expertise* - There is still a significant shortage of expertise in many organizations and financial institutions when it comes to effectively implementing ESG strategies. This knowledge gap makes it harder to develop and integrate ESG frameworks across companies and investment portfolios. Government and companies need to invest in training their staff, from

executives to analysts, on how to properly assess, measure, and report on ESG factors. Lack of expertise in ESG analysis and reporting could lead to poor decision-making and ineffective implementation of policies.

- *Regulatory and Legal Uncertainty* - ESG regulations are evolving rapidly, but there is still a significant lack of clear, consistent global regulatory frameworks to guide businesses and investors. Different countries and regions have their own ESG regulations, making compliance complex and costly for international organizations. At the same time, uncertainty in Climate Regulations is another major roadblock. While climate-related regulations are becoming more stringent, many companies remain uncertain about the future direction of climate policies and carbon pricing mechanisms. This uncertainty can create challenges in making long-term investments in ESG projects.
- *Cost of ESG Implementation* - For companies, implementing ESG strategies can be expensive. Adopting sustainable practices often requires initial investments in green technologies, supply chain improvements, or social responsibility initiatives. Additionally, companies may face costs related to ESG reporting and compliance.
- *Balancing Multiple Stakeholder Interests* – Implementation of ESG practices demand balancing the various stakeholders' interests including shareholders, employees, customers, and local communities. Different stakeholders may have conflicting expectations regarding ESG goals, such as prioritizing profit

versus sustainability or environmental protection versus economic development.

5. Conclusion

The implementation of ESG practices is essential for creating a more sustainable, socially responsible, and ethically sound global economy. However, achieving this requires overcoming several significant challenges, including data gaps, greenwashing, regulatory fragmentation, and cost concerns. To address these issues, businesses, investors, and regulators must collaborate to improve transparency, standardize ESG metrics, enhance education and expertise, and ensure robust oversight. While these challenges may seem daunting, they also present opportunities for innovation and leadership in the rapidly evolving field of ESG investing. With the right strategies, tools, and commitment, businesses and investors can unlock the full potential of ESG practices to drive positive change in the world. ESG taxonomy on other hand is still in a developmental phase in India, with significant progress but also considerable challenges in terms of consistency and enforcement. Corporations with glaring ESG practices are inclined to see long-term financial benefits, and investors are increasingly prioritizing sustainability in their portfolios. The development of robust and effective ESG taxonomies is crucial for driving sustainable investment and ensuring that capital is directed toward

environmentally responsible, socially inclusive, and well-governed companies. However, the challenges outlined above highlight the complexities involved in creating universally accepted and reliable ESG frameworks. To overcome these challenges, collaboration between regulators, businesses, investors, and industry groups is essential.

The solution lies in standardizing reporting practices, ensuring data quality and transparency, refining definitions of sustainability, and establishing enforcement mechanisms to prevent greenwashing. To unlock the full potential of ever evolving ESG taxonomies and making a meaningful contribution to a more sustainable global economy, we need to overcome these challenges. We would like to conclude that the current study was limited by the below mentioned points:

- Scope of analysis: Because this is conceptual research, the results are interpretive and might not adequately represent the dynamic intricacies of the real world.
- Dependency on secondary Data: The study is predicated on extant literature, which can differ in terms of focus and quality.
- Temporal restrictions: The conceptual framework may need to be updated on a regular basis to stay up to date due to the quick changes in sustainability policies and practices.

Future Scope

Although the integration of these frameworks appears promising, a number of obstacles still exist. The absence of standardisation in ESG indicators is a major problem that can result in disparities in the reporting and comparison of sustainability performance across sectors and geographical areas. Furthermore, businesses need to adjust to shifting standards and reporting requirements as regulatory frameworks like the green taxonomy continue to change. Future studies should concentrate on creating standardised ESG guidelines and investigating the operationalisation of these integrated approaches in diverse economic environments. Furthermore, empirical research that directly connects ESG practices to particular SDG results would improve our comprehension of the ways in which these pathways support sustainable development over the long run.

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Digital Financial Inclusion in South Asia: Gender Perspective

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Abstract

Purpose- Financial inclusion (FI) is critical to accomplishing the sustainable development goal of eliminating gender inequality & poverty. In-spite of South Asia making a great stride in recent years towards financial inclusion, but gender disparities are still very much present. In South Asia, women are more likely than men to rely on informal financial institutions, which can be costly and dangerous, rather than having access to formal financial services. This study aims to analyse gender disparities in account ownership, usage, and access to various financial

services across South Asian nations and identify relevant trends and patterns. It also examines the gender disparities in digital financial inclusion.

Design/methodology/approach- This study is cross-sectional study, based on secondary data retrieved from Findex Index 2021 from World Bank database & Financial Access Survey (IMF). Descriptive statistics are implemented to identify gender inequality in digital financial inclusion of selected South Asian Countries.

Findings of the study: The study found that bank account ownership is high in Sri Lanka, Maldives, and India, with gender gaps in Pakistan and Afghanistan. Mobile money accounts lead in Bangladesh, and there's an increase in India, Pakistan, and Nepal. Saving tendencies are high in Sri Lanka, Nepal, Maldives, India, Bhutan, and Pakistan but decreased in 2021 due to COVID. Online buying is prominent in Maldives and India, while there are challenges with inactive female accounts and gender gaps across various financial activities.

Contribution of the study and policy implications: This study adds considerably to the debate on financial inclusion in South Asia by offering a comprehensive overview of the region's financial habits. The findings' implications lead future research approaches and policy initiatives aimed at closing gender disparities, improving financial literacy, and promoting digital financial inclusion for sustained economic development in South Asia.

1. Introduction

Financial inclusion, a crucial driver of economic development, is a multifaceted concept influenced by a myriad of factors, ranging from cultural nuances to technological advancements. This research paper delves into the intricate financial landscape of South Asian countries, providing a comprehensive analysis of bank account ownership, digital transactions, gender disparities, and savings behaviours. The data encapsulates a period from 2011 to 2021, offering a longitudinal perspective on the evolving financial trends in this diverse and dynamic region.

South Asia, comprising nations such as Sri Lanka, Maldives, India, Afghanistan, Pakistan, Nepal, Bhutan, and Bangladesh, exhibits a rich tapestry of economic,

cultural, and social dynamics. The findings of this research shed light on the varying degrees of financial inclusion, emphasizing the need for targeted policies and interventions to address disparities and foster sustainable economic growth.

The research unfolds with a spotlight on the prevalence and distribution of bank accounts, revealing fascinating patterns. While countries like Sri Lanka, Maldives, and India boast high ownership rates, others, notably Afghanistan and Pakistan, exhibit lower levels. Notably, the gender gap in bank account ownership is a chronic theme, with exceptions in Sri Lanka and Nepal where strides have been made in narrowing this divide.

The exploration of debit and credit ownership and its correlation with digital transactions paints a nuanced picture of the region's financial ecosystem. Maldives, Sri Lanka, and India emerge as digital transaction leaders, yet gender disparities persist, presenting an avenue for targeted policy initiatives. Inactive accounts, particularly among females, pose challenges across the region, prompting a closer

examination of the reasons behind financial inactivity and potential strategies to re-engage individuals in the financial system.

The research also unveils the surge in mobile money accounts in Bangladesh and the evolving landscape in countries like India, Pakistan, and Nepal. Gender gaps in mobile money adoption underscore the importance of addressing barriers to digital financial services for women.

This research contributes significantly to the discourse on financial inclusion in South Asia by providing a holistic understanding of the region's financial behaviours. The implications drawn from the findings guide future research directions and policy interventions, aiming to bridge gender gaps, enhance financial literacy, and promote digital financial inclusion for long-term economic growth in South Asia.

2. Literature review & objectives of the study

Financial inclusion provides a safe place to save surplus income, access to credit and loans. It also plays an important role in providing banking and government services to the vulnerable sections of the society. Financial inclusion is a prerequisite for poverty and income inequality reduction (Zia & Prasetyo, 2018; Li, 2018; Omar & Inaba, 2020). According to Garg and Agarwal (2014), financial inclusion is the process of offering economically disadvantaged populations that lack access to even the most basic banking services relevant financial services at a fair price. Financial inclusion may enhance the financial situation and living situations of the vulnerable and impoverished, according to Borgohain & Borah (2015).

2.1 Empirical evidence on financial inclusion in South Asian countries.

Many studies have revealed that financial inclusion is low in South Asian countries. Mani (2016) claims that the use of banking services, credit and debit cards, bank borrowing, and savings deposits are all low in South Asian countries. Loukoianova *et al*. (2018) revealed that the Asia-Pacific region lags behind others in various key sectors such as online purchases, digital payments, mobile money, and mobile

transfers from governments. Alvi *et al.* (2020) mentioned that the South Asian region's solid banking infrastructure is unlikely to be able to reach large segments of the population, especially the impoverished. Qamruzzaman and Wei (2019) confirm the favourable association between financial innovation and financial inclusion in South Asian nations. However, Sarma (2016) opined that financial inclusion is influenced by a nation's income and financial development, yet higher income Asian nations do have some degree of financial inclusion. Hence, the current study attempts to analyze financial inclusion in South Asian countries. The study has framed first objective as follows.

Objective 1: To analyse the status of financial inclusion in South Asian countries.

Financial inclusion is crucial to achieve sustainable development goals in developing countries like India. Sundaram & Sriram (2016) mentioned that financial inclusion is prerequisite of for inclusive growth for countries like India. Bhattacharya (2020) said that financial inclusion is critical for India since it is home to a huge proportion of the world's impoverished. Chauhan (2013) stated that financial institutions have an essential and broad role to play in the growth of

financial inclusion in India. Laha (2015) revealed that the level of human development and financial inclusion are positively correlated in the context of the Indian economy.

2.2 Empirical evidence on the role of technology in improving financial inclusion.

Technology is playing a vital role in enhancing financial inclusion. ATMs, Mobile banking, internet banking, UPI, and E-wallet are enhancing overall financial inclusion (Myeni *et al.* 2020), particularly in low-developed countries. Hasan *et al.* (2023) found positive correlation between the digital literacy and usage of banking services. According to Kabir (2022), advancements in the supply of financial services and products via financial technology are significantly reducing gaps in financial inclusion. Lyons *et al.* (2020) said that more financial and digital inclusion is connected with considerable decreases in poverty, particularly food insecurity. Kede & Zogning (2022) revealed that 13.96% gap in accessing credit cards between males and females in the informal sector in Cameroon. Kurniasari *et al.* (2021) revealed that the use of digital technology improved financial inclusion in Indonesia.

Bansal (2014) mentioned that technology improves the level of financial inclusion in rural areas of India. Hence, this study analyses status of digital financial inclusion in South Asian countries. The study framed second objective as follows.

Objective 2: To analyse the status of digital financial inclusion of South Asian countries.

2.3 Empirical evidence on the role of financial inclusion in reducing gender inequality.

Financial inclusion plays a crucial role in reducing gender inequality particularly in in low-income countries like South Asia. Siddiquee (2023) opined that South Asian economies are progressing by adopting and implementing inclusive financial strategies. Thathsarani et al. (2021) said that financial inclusion has a lasting effect on human capital development in South Asian nations. (Badar *et al,* 2020). Aziz *et al.* (2022) mentioned that countries that encourage gender equality in the labor market appear to have more financially active women. According to Swamy (2014), women are more affected than men by financial inclusion in terms of income growth.

However, Asongu (2020) opined that financial access is a necessary but insufficient moderator of income disparity for increasing female involvement in the formal economy in Sub-Saharan Africa. Based on the above background, the study aims to analyse gender inequality in financial inclusion across South Asian countries. On the above background, study has framed third objective of the study as following.

Objective 3: To investigate gender-gap in financial inclusion of South Asian countries

Many studies have identified factors influencing financial inclusion. Bhanot *et al.* (2012) stated that income, financial information from multiple sources, and knowledge of self-help organisations are all critical elements contributing to financial inclusion. Ayyagari & Beck (2015) stated that the most identified hurdles to financial inclusion that policymakers may address are cost, physical accessibility, and a lack of identity. Cnaan *et al.* (2012) stated that social and personal hardship contribute to financial exclusion and should be considered important hurdles to financial inclusion.

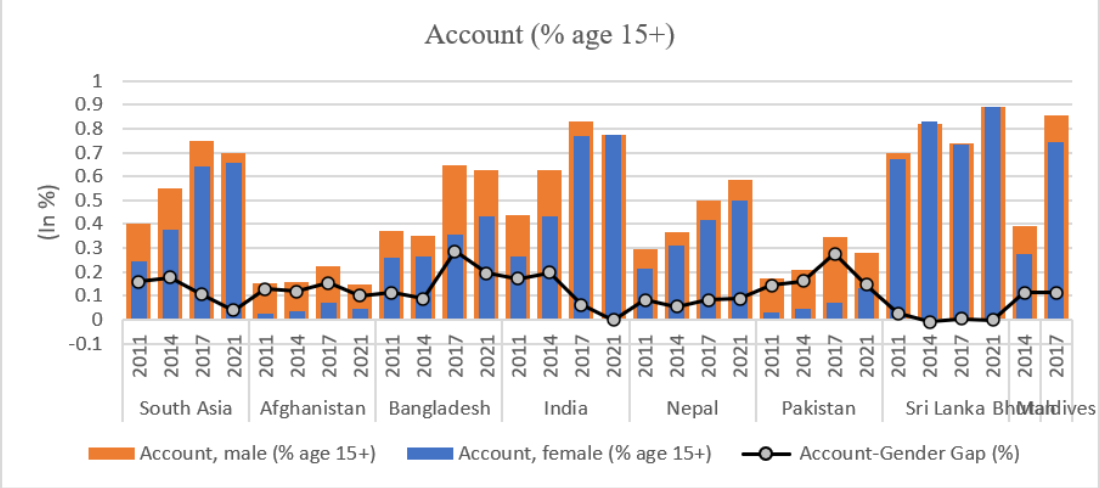
3. Research Methodology

It is a cross-sectional study based on the secondary data retrieved from the Findex index 2021 database of World Bank. Based on the availability of data, the study has selected eight South Asian counties (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka) for the study. Selected countries are from different income categories according to world Bank classification. Afghanistan falls in low-income, Maldives in upper-income class and other countries in middle-income category. Data is analysed with the help of descriptive statistics. The study reviewed status of financial inclusion of South Asian countries from 20211 to 2021 using Findex dataset.

4. Data Analysis & Discussion

Descriptive statistics is applied to analyse the data. The data analysis includes bank accounts, owning a debit or credit, in-active bank accounts, mobile Money Accounts, Saving tendency, Saving in financial institutions, Saving through Mobile Banking, Borrowing of Money from a formal financial institution or using a mobile

money account, digital payment transactions and, online buying through mobile phone or the internet.



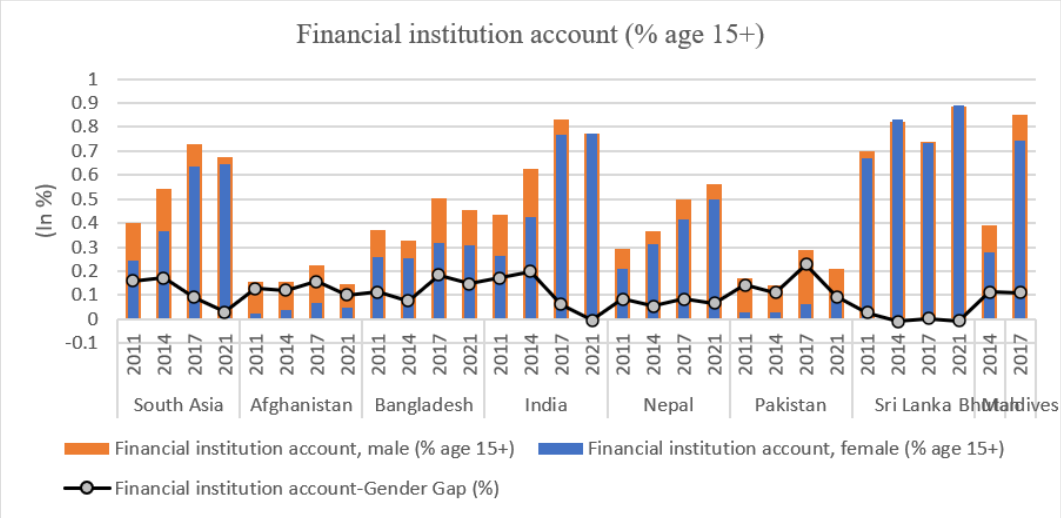
Source of data: Findex Index, World Bank 2021

Figure 1: Bank Accounts

Figure 1 shows increased in overall banks accounts for south Asian countries from 2011 to 2017. However, it has decreased in Afghanistan, Bangladesh, India and Pakistan in 2021. More than 80 percent households have Banks accounts in Sri Lanka followed by Maldives and India indicating high financial inclusion in these countries. However, less bank accounts are observed in Afghanistan and Pakistan.

Nepal showed progress in opening bank accounts from 30 to 60 percent from 2011 to 2021.

Except for Pakistan and Afghanistan, the gender disparity in bank account opening has decreased between 2011 and 2021. Gap is very less Shri Lanka followed by Nepal and India.

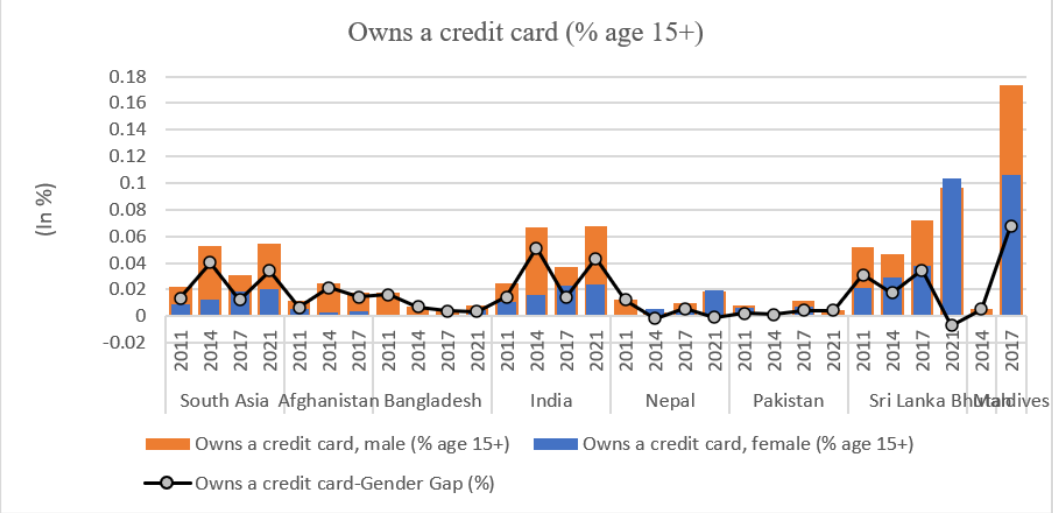


Source of data: Findex Index, World Bank 2021

Figure 2: Bank Account with Financial institution

Financial institution accounts are more in Sri Lanka, Maldives and India. Less than 30 percents bank accounts are in financial institutions in Pakistan and Afghanistan. Nepal showed increasing in financial institution accounts from 2011 to 2021 (Figure 2).

Gender-Gap in financial institution accounts has reduced in South Asia except Afghanistan, Bangladesh and Pakistan. Gender-gap in financial institution account is negligible in Sri Lanka.



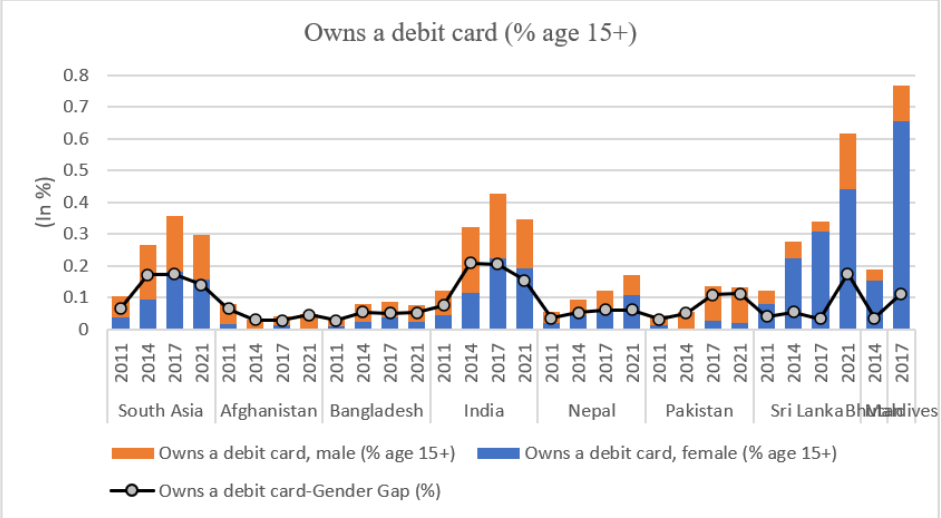
Source of data: Findex Index, World Bank 2021

Note: Data was not available of Afghanistan of 2021. Female data was not available some countries in some years.

Figure 3: Owns a credit card (% age 15+)

Figure 3 showed increased in owing a credit card from 2011 to 2021 except little decrease in some countries in 2021. Maldives tops in owing credit cards followed by Sri Lanka and India. However, penetration of credit cards is less in Afghanistan, Bangladesh, Pakistan and Bhutan. Though, the penetration of credit cards is low in Nepal, it showed increased trend from 2011 to 2021.

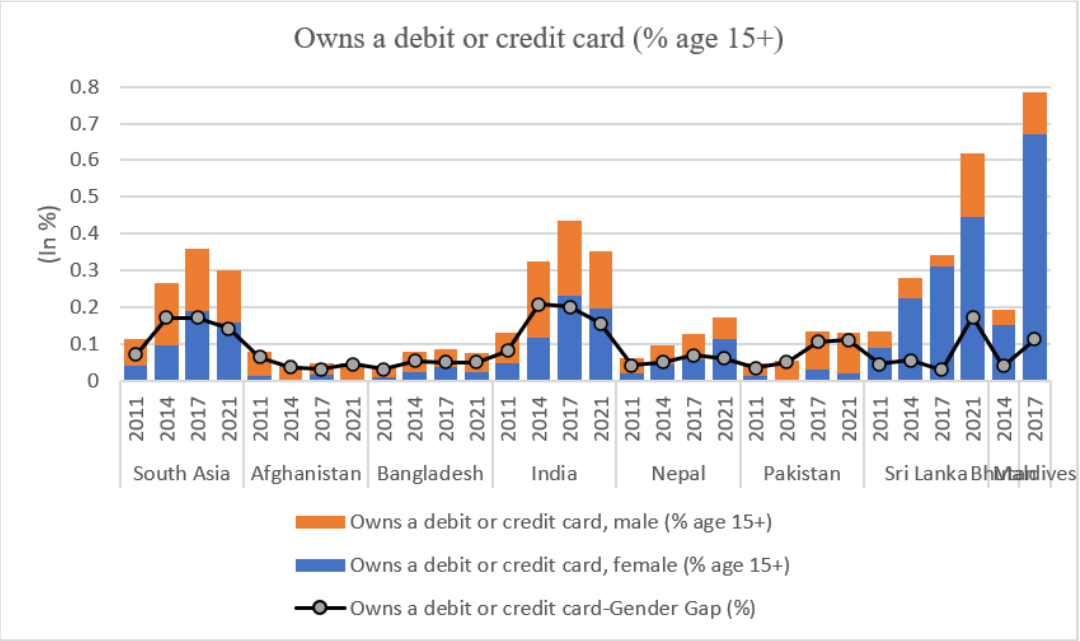
Gender-gap in owing credit card is high Maldives, India and Afghanistan. In contrast, it less in Nepal. Though gender-gap in owing debit card was more in Sri Lank in2011 to 2017, female owned more credit card than male in 2021.



Source of data: Findex Index, World Bank 2021

Figure 4: Owns a debit card

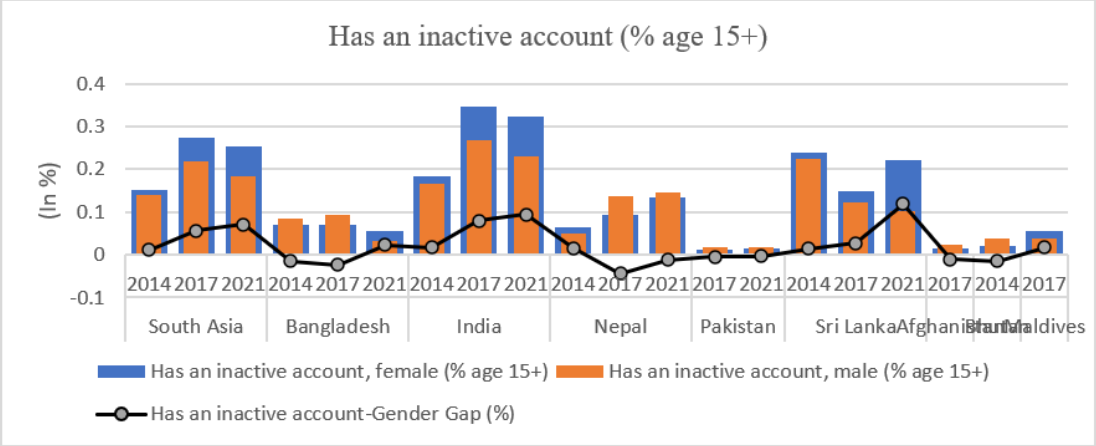
Figure 4 indicates that though owning a debit card is more in Maldives, Sri Lanka and India in compared to other countries, gender-gap owning a debit card is also high in these countries. In contrast, penetration of debit cards is low in Afghanistan, Bangladesh, and Pakistan. Though the owing debit cards is low in Nepal, it has increased from 2011 onwards.



Source of data: Findex Index, World Bank 2021

Figure 5: Ownership of credit and debit card

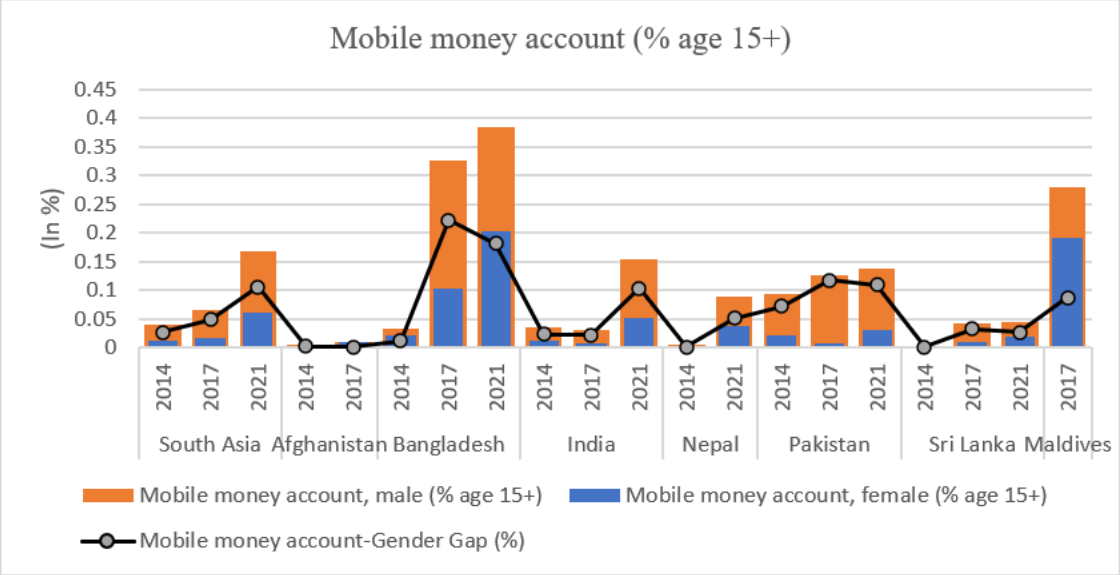
Figure 5 indicates that owning a debit or credit is more in Maldives, Sri Lanka and India compared to other countries indicating high digital transactions. However, gender-gap in owing debit or credit card is high in these countries compared to other countries. Owning debit or credit is very low in Afghanistan, Bangladesh, Pakistan, Nepal and Bhutan which indicates low digital transactions.



Source of data: Findex Index, World Bank 2021

Figure 6: Has an inactive account

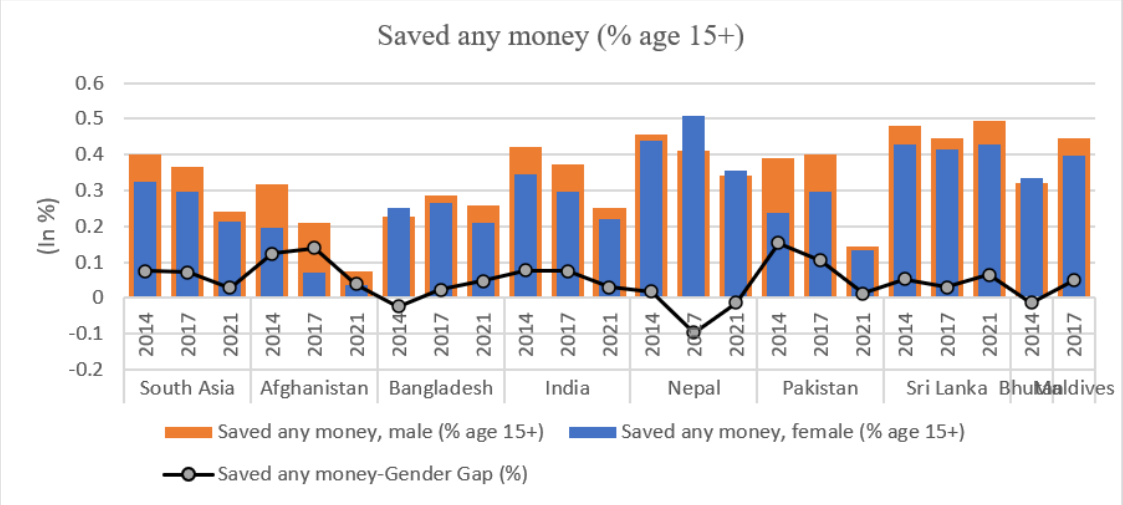
Figure shows that in-active accounts of female is high in all the countries except Afghanistan, Bhutan, Pakistan, Nepal and Bangladesh. However, in-active accounts of female are increased in Bangladesh in 2021. In contrast, in-active account of female is more India, Sri Lanka, Maldives and overall South Asia.



Source of data: Findex Index, World Bank 2021

Figure 7: Mobile banking

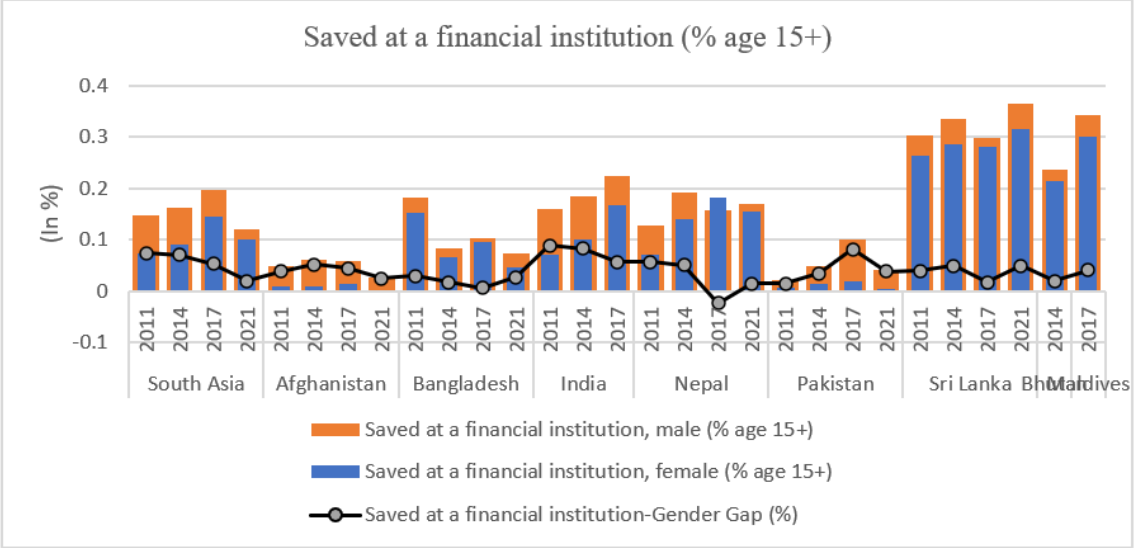
Figure 7 indicates that mobile money accounts are high in Bangladesh from 2017 to 2021 followed by Maldives as compared to other countries. However, mobile money accounts has increased in India, Pakistan and Nepal in 2021. Gender-gap in Mobile money accounts is high in Bangladesh, Pakistan, India and Maldives. (Provide-reasons)



Source of data: Findex Index, World Bank 2021

Figure 8: Saving in Banking

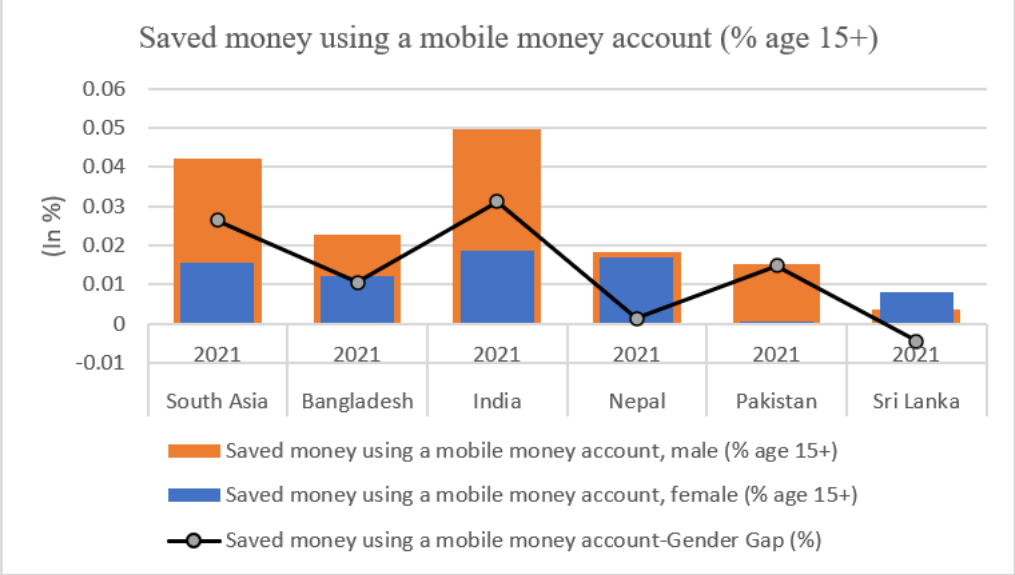
Figure 8 indicates that tendency of saving money is high in Sri Lanka, Nepal, Maldives, India, Bhutan and Pakistan. However, it has decreased in the 2021 in all the countries except Sri Lanka. Gender- gap is high in saving tendency in Pakistan, Afghanistan and India.



Source of data: Findex Index, World Bank 2021

Figure 9: Saving with financial institution

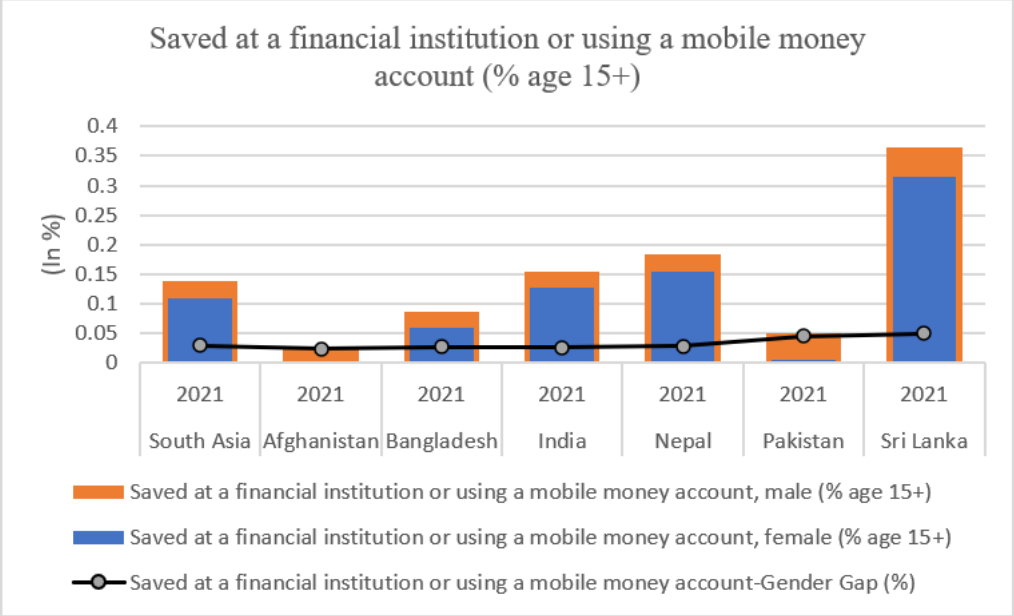
Figure 9 indicates that saving in financial institutions are more in Sri Lanka, followed by Maldives, Bhutan, India and Nepal. It lesser in Afghanistan, Pakistan and Bangladesh. This indicates that level of income influences the saving at financial institutions. Overall saving in South Asia increased from 2011 to 2017 but it decreased in 2021 as an impact of Covid.



Source of data: Findex Index, World Bank 2021

Figure 10: Savings though Mobile banking

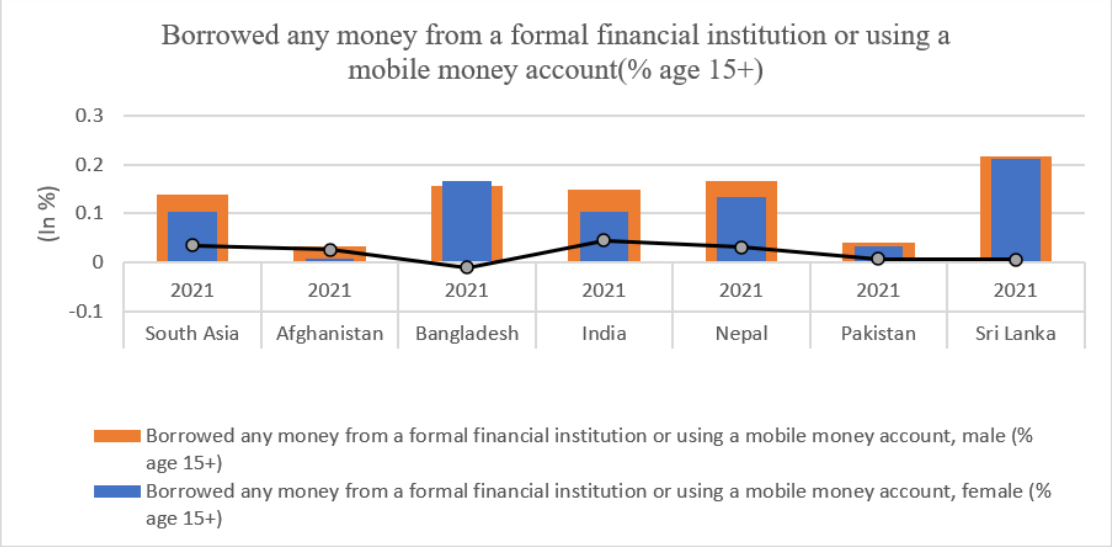
Figure 10 shows that Money is saved more through mobile account in India, however, gender-gap is also more in India as compared to other countries. Saving through mobile banking by female is close to male in Nepal. Whereas, female are saving more than male through mobile banking Sri Lanka.



Source of data: Findex Index, World Bank 2021

Figure 11: Saving with mobile banking or financial institution

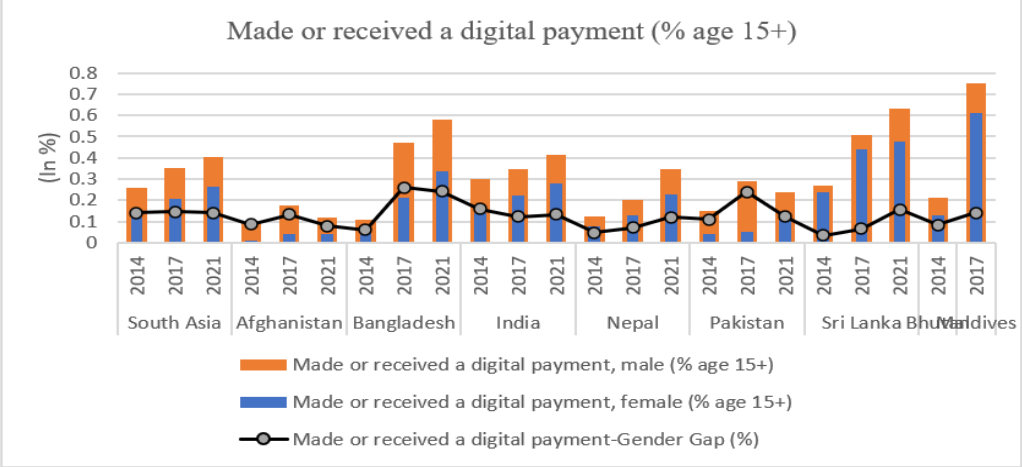
Figure 11 shows that money saved at financial institution or using mobile money account is more in Sri Lanka as compared to other countries. In India and Nepal, around 15 to 20 percent saving is at financial institution or using a mobile money. Gender-gap of saving at financial institution or using mobile money account is high in Pakistan.



Source of data: Findex Index, World Bank 2021

Figure 12: Money borrowing from mobile banking or financial institutions

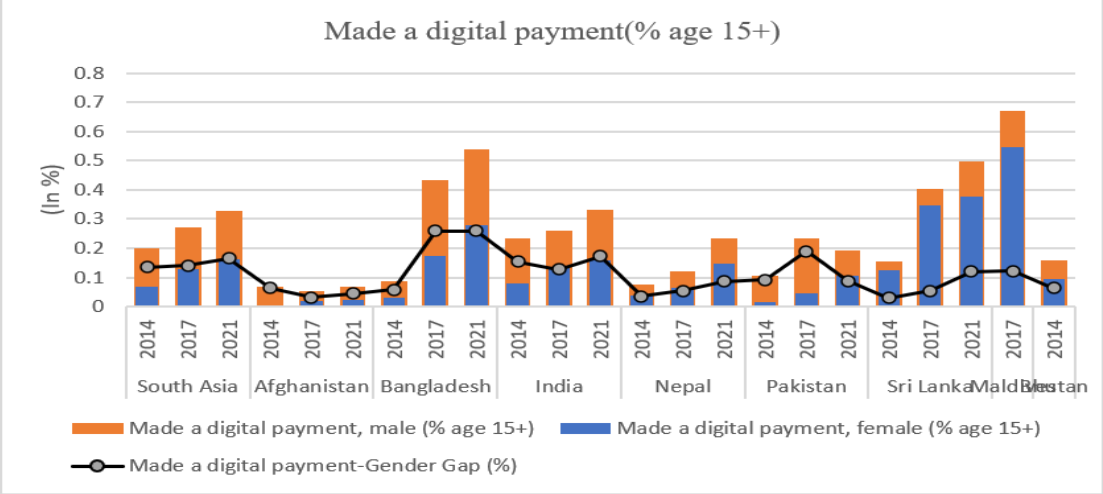
Figure 12 indicates that money is borrowed from a formal financial institution or using a mobile money account is more Sri Lanka, Bangladesh, Nepal and India, however, it is low in Afghanistan and Pakistan. Male have borrowed more than female in India, Nepal and Afghanistan. In contract, female are borrowing more in Bangladesh. Female are borrowing equal to male in Sri Lanka.



Source of data: Findex Index, World Bank 2021

Figure 13: Transaction though digital mode

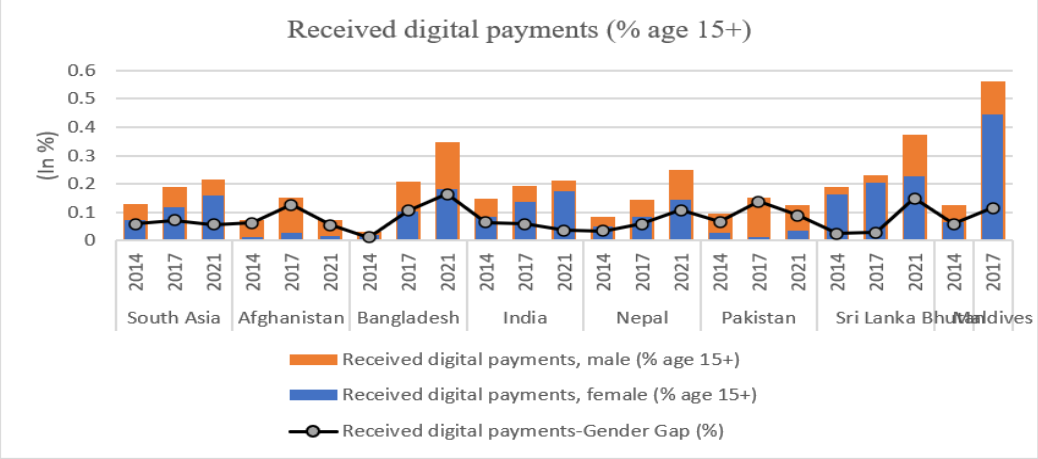
Figure 13 indicates that transaction of digital payments are more in Maldives, Sri Lanka, Bangladesh and India. However, transaction of digital payment are less in Afghanistan, Pakistan and Bhutan. Digital payment transaction was less in Nepal in 2014 and 2015, however it has increased in 2021. Male have more digital payment transactions than female in Bangladesh, India and Pakistan as compared to other countries.



Source of data: Findex Index, World Bank 2021

Figure 14: Use of digital payment

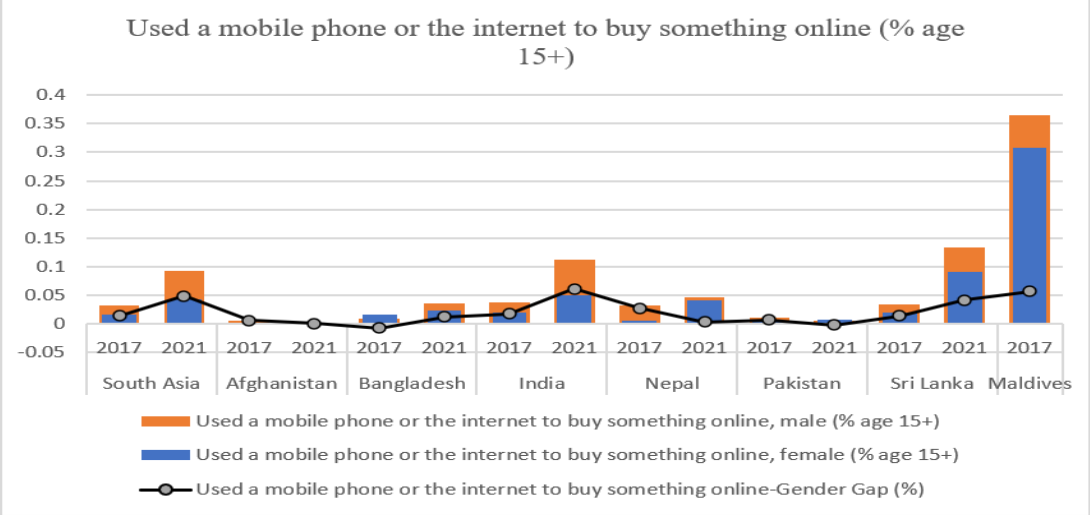
Figure 14 indicates that digital payments are made more in Maldives, Sri Lanka, Bangladesh and India. In contrast, digital payment are made less in Afghanistan, Pakistan and Bhutan. Digital payment was made less in Nepal in 2014 and 2015, however it has increased in 2021. Digital payment made by male is more than female in Bangladesh, India and Pakistan as compared to other countries.



Source of data: Findex Index, World Bank 2021

Figure 15: Received payment through digital mode

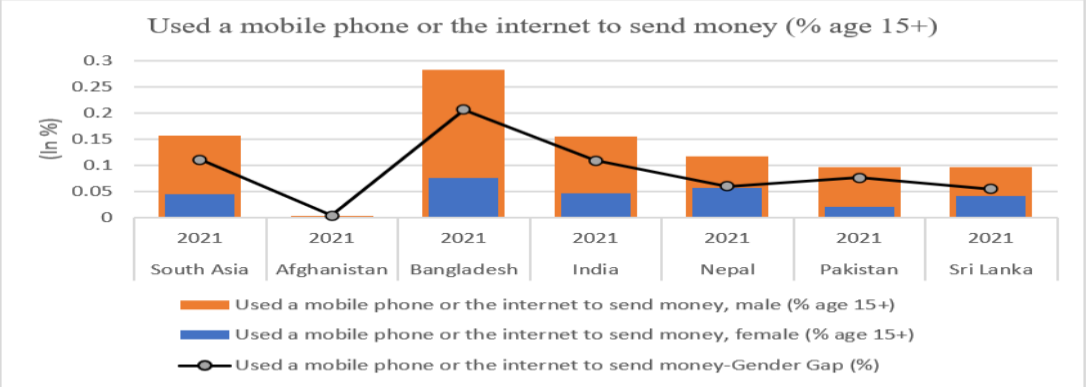
Figure 15 indicates that digital payments are received more in Maldives, Sri Lanka and Bangladesh as compared to other countries. In contrast, digital payments received is low in Afghanistan, Pakistan and Bhutan. Digital payments received has increased after 2017 in India and Nepal. Gender-gap in receiving digital payments is more in Bangladesh, Afghanistan and Pakistan as compared to other countries.



Source of data: Findex Index, World Bank 2021. Note: Data of Bhutan is not available.

Figure 16: Online purchase using mobile or internet

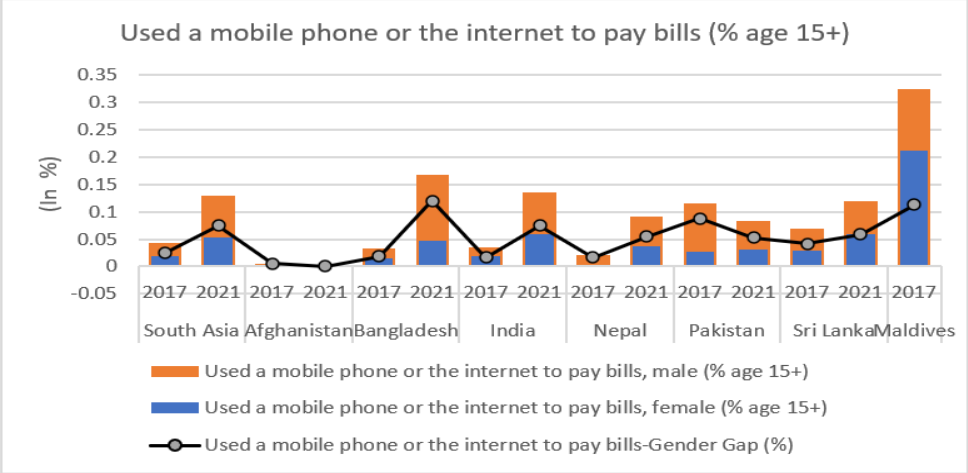
Figure 16 shows that use of mobile phone or internet in online buying is more in Maldives as compared to other countries. Usage of mobile or internet for online buying is low in Afghanistan, Pakistan, Bangladesh and Nepal. The online buying using mobile or internet increased in Sri Lanka and India in 2021. Gender-gap is also more for online buying in Sri Lanka and India.



Source of data: Findex Index, World Bank 2021. Note: data of Bhutan and Maldives is not available.

Figure 17: Sending money through mobile or internet

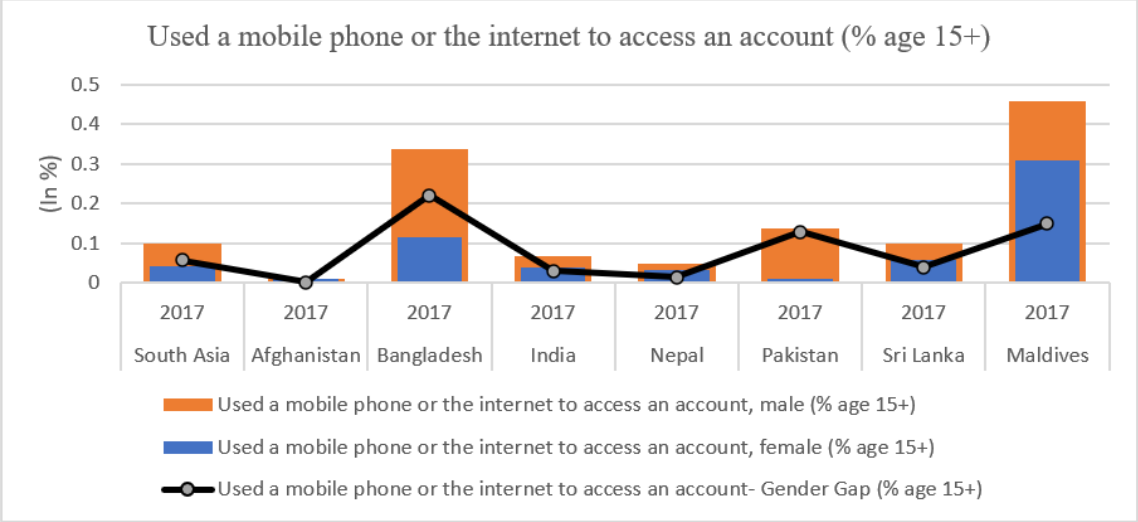
Figure 17 shows that Bangladesh is the country that uses mobile phones or the internet the most for money transfers, followed by India, Nepal, Pakistan, and Sri Lanka. However, gender-gap in these countries is also high. Usage of mobile phone or internet to send money is very low in Afghanistan.



Source of data: Findex Index, World Bank 2021

Figure 18: Bill payment through mobile or internet

Figure 18 shows that, with the exception of Pakistan, most nations saw a growth in the use of mobile phones or the internet to pay bills in 2021. More people in Bangladesh and the Maldives use their phones or the internet to pay their bills, followed by India and Sri Lanka. In Afghanistan, however, very few people use their phones or the internet to pay their bills.



Source of data: Findex Index, World Bank 2021. Note: data of other years is not available.

Figure 19:Accessing account through mobile phone or internet

Figure 19 shows that, in comparison to other nations in 2017, Bangladesh and the Maldives had higher rates of using mobile phones or the internet to access bank accounts. In Bangladesh, Pakistan, and the Maldives, there is a significant gender disparity in the usage of mobile phones or the internet to access bank accounts.

5. Findings of the study

The findings of the study are presented in the line with analysis of data as follows.

5.1 Bank Accounts

The study revealed that more than 80 percent households have Banks accounts in Sri Lanka followed by Maldives and India. However, less bank accounts are observed in Afghanistan and Pakistan. Whereas in Nepal, opening bank accounts are increased from 30 to 60 percent from 2011 to 2021. Gender-gap in opening bank accounts is decreased in all the countries except Pakistan and Afghanistan from 2011-2021. Gender-gap is very low Shri Lanka followed by Nepal and India.

5.2 Owning a debit or credit

The study found that owning a debit or credit is more in Maldives, Sri Lanka and India compared to other countries indicating high digital transactions. However, gender-gap in owing debit or credit card is high in these countries compared to other countries. Owning debit or credit is very low in Afghanistan, Bangladesh, Pakistan, Nepal and Bhutan which indicates low digital transactions.

5.3 In-active bank accounts

The study found that in-active accounts of female is high in all the countries except Bhutan, Pakistan, Nepal and Bangladesh. In contrast, in-active account of female is more India, Sri Lanka, Maldives and overall South Asia.

5.4 Mobile money accounts

The study discovered that mobile money accounts are high in Bangladesh from 2017 to 2021 followed by Maldives as compared to other countries. However, mobile money accounts has increased in India, Pakistan and Nepal in 2021. Gender-gap in Mobile money accounts is high in Bangladesh, Pakistan, India and Maldives.

5.5 Saving tendency

The study found that tendency of saving money is high in Sri Lanka, Nepal, Maldives, India, Bhutan and Pakistan. However, it has decreased in the 2021 in all the countries except Sri Lanka. Gender- gap is high in saving tendency in Pakistan, Afghanistan and India.

5.6 Saved in financial institutions

The study discovered that saving in financial institutions are more in Sri Lanka, followed by Maldives, Bhutan, India and Nepal. It lesser in Afghanistan, Pakistan and Bangladesh. This indicates that level of income influences the saving at financial institutions. Overall saving in South Asia increased from 2011 to 2017 but it decreased in 2021 as an impact of Covid.

5.7 Saved through mobile banking

In 2001, money is saved more through mobile account in India, however, gender-gap is also more in India as compared to other countries. Saving through mobile banking by female is close to male in Nepal. Whereas female is saving more than male through mobile banking Sri Lanka.

5.8 Borrowing of Money from a formal financial institution or using a mobile money account

According to the report, borrowing from a formal financial institution or using a mobile money account is more common in Bangladesh, Nepal, India, and Sri Lanka

but less common in Afghanistan and Pakistan. In India, Nepal, and Afghanistan, men have taken out more loans than women. In contrast, women in Bangladesh are taking out more loans. In Sri Lanka, women borrow on par with men.

5.9 Made or received a digital payment

The study discovered that transaction of digital payments are more in Maldives, Sri Lanka, Bangladesh and India. However, transaction of digital payment are less in Afghanistan, Pakistan and Bhutan. Digital payment transaction was less in Nepal in 2014 and 2015, however it has increased in 2021. Males have more digital payment transactions than female in Bangladesh, India and Pakistan as compared to other countries.

5.10 Online buying through mobile phone or the internet

The study found that use of mobile phone or internet in online buying is more in Maldives as compared to other countries. It is low in Afghanistan, Pakistan, Bangladesh and Nepal. it increased in Sri Lanka and India in 2021. Gender-gap is also more for online buying in Sri Lanka and India.

6. Implications of the study

The implication of the study is presented in two categories such as implication for Policymakers and implication for future research.

6.1 Policy Implications

6.1.1 Gender-Inclusive Financial Policies

Policy interventions should prioritize the development and implementation of gender-specific financial initiatives. This includes targeted efforts to bridge the gender gap in bank account ownership, digital transactions, and online buying. Governments and financial institutions should collaborate to design and execute policies that promote financial inclusion and economic empowerment for women.

6.1.2 Financial Literacy Programs

Policymakers should invest in comprehensive financial literacy programs, with a focus on increasing awareness and understanding of digital financial services. These programs should address the specific needs of different demographics, aiming to enhance financial education among women and marginalized groups. By fostering

financial literacy, policymakers can empower individuals to make informed decisions about saving, borrowing, and utilizing digital payment methods.

6.1.3 Mobile Money Promotion:

Governments and financial institutions should collaborate on strategies to promote mobile money adoption. This may involve targeted marketing campaigns, incentives, and educational initiatives. Understanding the unique factors influencing mobile money usage in different countries can guide the development of effective policies to encourage its widespread adoption.

6.2 Research Implications:

6.2.1 In-Depth study on inactivity trend

Researchers should conduct in-depth studies to explore the reasons behind the prevalence of inactive female accounts. This research can uncover the underlying factors contributing to financial inactivity and inform the development of tailored interventions to encourage sustained engagement.

6.2.2 Impact of cultural factors on online buying

Further research is needed to explore the role of cultural factors in shaping online buying patterns. Understanding cultural nuances and preferences can guide the design of strategies to bridge the digital divide and promote online transactions in a culturally sensitive manner.

6.2.3 Longitudinal studies on COVID-19 impact

Researchers should conduct longitudinal studies to assess the long-term impact of the COVID-19 pandemic on savings behaviour. This research can provide insights into the lasting effects of external shocks on financial habits and inform the development of strategies to build financial resilience.

6.2.4 Evaluation of mobile banking impact

Comprehensive evaluations should be conducted to assess the impact of mobile banking on financial inclusion and savings behaviour. Understanding how mobile banking contributes to equitable financial participation, especially among women, can inform policymakers and financial institutions on the effectiveness of such initiatives.

These policy and research implications aim to guide future endeavours in fostering financial inclusion, reducing gender disparities, and promoting sustainable economic development in South Asian countries.

7. Conclusion

In conclusion, the financial landscape in South Asian countries exhibits a diverse range of trends and behaviours. While bank account ownership is widespread, there are variations in the adoption of digital transactions and financial inclusion. The study highlights the impact of gender disparities on financial activities, with notable differences in debit/credit ownership, mobile money accounts, and digital payment transactions.

Sri Lanka, Maldives, and India stand out with high levels of financial engagement, yet challenges persist, particularly with inactive female accounts. The increasing trend in saving tendencies across several nations contrasts with a decline in overall savings in 2021, attributed to the global impact of the COVID-19 pandemic.

Mobile banking and online buying patterns reflect both advancements and disparities, with certain countries leading in technology adoption while others lag behind. The findings underscore the need for targeted interventions to address gender gaps and enhance financial literacy, aiming for more inclusive and resilient financial ecosystems across South Asia. The intricate interplay of economic factors, cultural nuances, and technological advancements emphasizes the importance of tailored strategies to foster sustainable financial development in the region.

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Growth Analysis of NIFTY 100 ESG Index V/S NIFTY 100 Index – A Comparative Study

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Abstract

This research compares the NIFTY 100 ESG Index and the NIFTY 100 Index to study sustainable investing in the Indian fund market. The study reviews historical trends, risk-adjusted returns, and macroeconomic effects to determine whether ESG companies exhibit superior growth, stability, and risk resistance compared to traditional benchmarks. The study includes macroeconomic variables such as GDP growth, inflation, and foreign investment and applies quantitative models such as GARCH and cointegration analysis. The research aims to provide knowledge to

investors, policymakers, and businesses on the long-term financial effects of ESG investing in India. The findings offer recommendations on the risk-adjusted returns and stability of ESG investments and inform regulators on how macroeconomic effects influence ESG investments, allowing the formulation of sustainable investment frameworks.

1. Introduction

Growing emphasis on sustainable investing has seen the development of ESG indices that track companies that are doing well on environmental, social, and governance (ESG) criteria (Friede et al. 2015; Eccles and Klimenko 2019). NIFTY 100 ESG Index and NIFTY 100 Index are leading benchmarks in this sense, capturing the performance of companies that have superior ESG standards compared to the broader market (Bahl and Shankar 2022).

The NIFTY 100 ESG Index includes companies with good ESG compliance based on pre-specified scoring parameters, whereas the NIFTY 100 Index includes the largest 100 Indian companies based on market capitalization, irrespective of whether they possess ESG issues (Reddy and Gordon 2021). A comparison of these indices helps investors ascertain whether companies with strong ESG profiles yield

competitive or superior returns compared to conventional equity benchmarks (Chatterjee et al. 2023).

A comparative analysis of the NIFTY 100 ESG Index and the NIFTY 100 Index show that they differ in historical performance, risk-return, and impact of macroeconomic factors on return (Sahni et al. 2022). With increasing adoption of ESG considerations in investment, it is crucial to understand how green companies perform against conventional market indexes (Bansal et al. 2021; Kumar and Bhattacharya 2023). An investigation into whether ESG investments provide better risk-adjusted returns, long-run consistency, and stability compared to conventional market benchmarks (Chowdhury and Sahu 2020).

Macroeconomic indicators such as GDP growth, inflation, foreign direct investment (FDI), monetary policy, and interest rates play major roles in dictating financial market trends (Mishra and Mishra 2021). They both indirectly influence and determine ESG as well as non-ESG investments by modifying corporate profitability, investor sentiments, and overall market liquidity (Patnaik et al. 2023). Firms incorporating an ESG orientation are capable of responding diversely to macroeconomic shocks with respect to business models built upon sustainability, regulator support, as well as shareholder demand for values-based investing (Sharma and Saxena 2022). It provides remarkable insights into economic conditions influencing sustainable investment performance.

By comparing these indices in the Indian market, this research hopes to provide empirical evidence on whether ESG investing is better in terms of growth prospects and resilience compared to traditional equity benchmarks. Research contributes to the current literature on sustainable finance by providing answers to the most important questions on financial returns, risk, and investor's decisions in the Indian equity market.

Our findings have implications for retail and institutional investors to make investment decisions based on ESG performance trends. Policymakers and regulators can also use the study in an attempt to determine the role that macroeconomic factors play in the determination of ESG investments in order to aid in the development of sustainable investment guidelines that can help in the realization of long-term economic and environmental goals. A better understanding of the ESG investment patterns in the Indian economy is attained in terms of the evolving relationship between profitability and sustainability.

2. Research Gap, Research Questions, and Hypotheses

Sustainable investing has become more popular as investors increasingly take into account Environmental, Social, and Governance (ESG) considerations while making

portfolio decisions. Empirical evidence supports that there is high correlation between ESG ratings and equity returns such that companies that rank high on ESG dimensions have better risk-adjusted return (Friede et al., 2015; Khan et al., 2016). Empirical evidence supports the view that companies with good ESG practices have lower cost of capital, higher operational efficiency, and better financial performance, appealing to institutional as well as retail investors (Eccles et al., 2014; Giese et al., 2019). Comparability and reliability of the performance of ESG indexes are, however, controversial due to variations in methodologies of ESG ratings and differences in uniformity of disclosure expectations across markets (Kumar & Bhattacharya, 2023). Disparities in the scoring metrics for ESG for different rating firms also cause divergence in categorization of stocks and thus divergence in the credence of investment decisions based on ESG indicators (Berg et al., 2022).

In spite of such issues, ESG indices became increasingly popular globally with investors using them as sustainable investment benchmarks. In the Indian context, the NIFTY 100 ESG Index, which tracks companies based on their ESG performance, is known to be a primary benchmark for the measurement of the financial sustainability of ESG-themed investments. Studies have established that ESG indices can be a source of strength during such periods, with less volatility and superior long-term returns compared to conventional indices (Auer & Schuhmacher, 2016; Albuquerque et al., 2020). Issues remain, however, relating to the balance between ESG regulation and financial returns, particularly in emerging economies

where regulatory frameworks and corporate sustainability disclosure are in their initial stages.

This research adds to the literature by measuring the NIFTY 100 ESG Index performance against the NIFTY 100 Index performance using a comprehensive financial and economic analysis. The research tries to provide insights into the efficacy of ESG investment in the Indian economy by analyzing risk-adjusted returns, volatility, and sectoral exposures. The research also examines how ESG factors affect portfolio diversification, investment sentiment, and long-term shareholder value creation. Empirical findings here will provide crucial implications for policymakers, asset managers, and investors who want to balance sustainability goals and finance performance.

RQ1: Are the monthly return of the NIFTY 100 ESG Index and the NIFTY 100 Index significantly different?
H1: The monthly return of the NIFTY 100 ESG Index and the NIFTY 100 Index does not significantly different.

The motivation behind this research stems from the increasing prominence of Environmental, Social, and Governance (ESG) investing in India and the need to evaluate its financial implications. While global studies suggest that ESG-compliant companies tend to exhibit lower risk and stable long-term returns (Fatemi et al.,

2018; Amel-Zadeh & Serafeim, 2018), findings in the Indian context remain inconclusive. (Bhardwaj & Panchal, 2022) and (Kumar & Tiwari, 2023) highlight that the adoption of ESG investing in India has gained momentum due to regulatory developments and growing investor awareness. However, (Mishra & Sharma, 2021) argue that inconsistencies in ESG rating methodologies may impact index performance, leading to variations in returns between ESG indices and conventional benchmarks. Additionally, (Gupta et al., 2022) find that while Indian ESG indices demonstrate resilience during market downturns, they do not consistently outperform traditional market indices.

This study examines whether the monthly returns of the NIFTY 100 ESG Index and the NIFTY 100 Index significantly differ. Hypothesis (H1) posits that the monthly returns of both indices are not much different, indicating that ESG considerations do not necessarily lead to excess returns or performance deviations. (Patel & Mehta, 2022) note that while ESG investing aligns with long-term sustainability goals, short-term return patterns in India remain ambiguous due to sectoral biases and evolving corporate disclosures. If the analysis reveals a significant difference in returns, it would imply that ESG factors influence stock performance, either by attracting investor preference or by limiting exposure to high-performing non-ESG stocks. Conversely, if no significant difference is found, it suggests that ESG compliance does not materially impact investment returns. This research contributes to the growing discourse on sustainable investments in India by providing empirical

insights that can aid investors, policymakers, and financial analysts in making informed ESG investment decisions.

RQ2: Are the risk-adjusted performance measures (Sharpe, Sortino, Omega, and Calmar ratios) of the NIFTY 100 ESG Index significantly different from those of the NIFTY 100 Index?
H2: The Sharpe, Sortino, Omega, and Calmar Ratios (risk-adjusted performance ratios) of the NIFTY 100 ESG Index are comparable to the NIFTY 100 Index.

The selection of this research question and hypothesis is driven by the need to examine the risk-adjusted performance of ESG investments in India because investors are increasingly interested in both returns and risk management. While international studies indicate that ESG-focused portfolios are less risky and offer better downside protection (Broadstock et al., 2021; Fatemi et al., 2018), Indian studies provide mixed evidence on the risk-return tradeoff of ESG investments. Mishra & Sharma (2021) and Gupta et al. (2022) studies indicate that Indian ESG indices can offer stability in the declining market but may not necessarily offer higher risk-adjusted returns compared to traditional indices. Patel & Mehta (2022) also indicate that sectoral biases and shifting ESG disclosure patterns in India can influence portfolio risk exposure and influence key risk-adjusted performance measures such as the Sharpe, Sortino, Omega, and Calmar ratios.

The hypothesis (H2) does not assume any material difference in the risk-adjusted performance between the NIFTY 100 ESG Index and the NIFTY 100 Index as a neutral benchmark to test if ESG integration enhances portfolio risk management. Kumar & Tiwari (2023) research highlights that while ESG investments can lower the downside risk, their risk-adjusted performance depends on market conditions and investor sentiments. Whether differences are material or not, perhaps ESG indices either provide greater downside protection because they do not include high-risk sectors or outperform because they are constrained in stock selection. If there is no material difference, it implies that ESG compliance per se does not impact risk-adjusted returns. This research BEGINS to contribute to the evolving debate on sustainable finance in India, and empirical evidence can assist investors, fund managers, and policymakers in structuring ESG-based investment portfolios in accordance with risk and return goals.

RQ3: How much different is the persistence of volatility and market shock sensitivity of the NIFTY 100 ESG Index compared to the NIFTY 100 Index?
H3: Volatility persistence and shock response in the NIFTY 100 ESG Index are identical to those in the NIFTY 100 Index.

The choice of this research question and hypothesis is motivated by the necessity to evaluate the stability and resilience of ESG-based investments in India, especially in the context of market shocks and persistence of volatility. Although global research

attests that ESG-compliant portfolios are less volatile due to their focus on governance and risk management practices (Broadstock et al., 2021; Fatemi et al., 2018), Indian research offers mixed evidence on the nature of volatility of ESG indices. Research by Mishra & Sharma (2021) and Gupta et al. (2022) confirms that the NIFTY 100 ESG Index is relatively less volatile under normal market conditions but may not always offer superior risk protection under extreme market conditions. Further, Patel & Mehta (2022) point out that ESG portfolios in India are prone to sectoral biases, which can affect their response to macroeconomic shocks and result in differential volatility persistence compared to traditional indices.

The hypothesis (H3) anticipates no material difference in the persistence of volatility and market shock response of the NIFTY 100 ESG Index and the NIFTY 100 Index, assuming a neutral stance to check the strength of ESG-based investments. Kumar & Tiwari (2023) in their research believe that while ESG investing is consistent with long-term financial health, its short-term volatility dynamics rely on evolving corporate disclosure norms and regulatory changes in India. If there is material difference regarding volatility persistence and market shock response, then it would mean that ESG indices either indicate more stability due to their exclusion of high-risk sectors or indicate higher sensitivity due to their over-weighting in particular sectors. If there is no material difference, then it would mean that ESG compliance is not necessarily bound to alter the volatility dynamics of an index. This study adds to the India ESG investing discussion by presenting empirical results, which can

prove beneficial to investors, risk managers, and policymakers in evaluating the risk behavior of sustainable investments in different market scenarios.

RQ4: Whether the NIFTY 100 ESG Index and the NIFTY 100 Index are equally sensitive towards macroeconomic drivers such as interest rate, inflation rate, GDP rate, and the price of crude oil?

H4: NIFTY 100 ESG Index and NIFTY 100 Index both react similarly to macroeconomic drivers such as interest rates, inflation, GDP growth, and crude oil prices.

The selection of this research question and hypothesis is necessitated by the need to analyze the manner in which ESG-based investment in India responds to key macroeconomic variables, which are major determinants of stock market behavior. While global evidence suggests that ESG indices may respond differently to macroeconomic variables depending on sectoral bias and investor sentiment (Brière & Ramelli, 2021; Nofsinger & Varma, 2014), Indian studies provide inconclusive results. Chakrabarti & Sen (2022) and Agarwal & Bansal (2023) carry out studies that indicate, while the NIFTY 100 ESG Index has proved to be robust in times of economic distress, its response to interest rates, inflation, GDP growth, and crude oil prices continues to be in sync with the overall market. Sharma & Iyer (2022) also hypothesize that ESG indices in India will be less sensitive to energy- and commodity-based sectors, whose response to macroeconomic shocks would be

dissimilar in comparison to traditional indices. The hypothesis (H4) takes into account the possibility that the NIFTY 100 ESG Index and the NIFTY 100 Index are equally sensitive to the macroeconomic conditions, and this is used as a baseline to check if ESG integration has any material effect on the responsiveness of an index to the economy or not. A study by Mehta & Kapoor (2023) observes that while ESG-focused firms can benefit from regulatory favors and increased investor confidence, their stock performance still remains susceptible to overall economic conditions. If there is differential sensitivity, then it would suggest that ESG indices are either less risky or very risky because of excessive exposure to sectoral concentration. However, if no differential sensitivity is observed, then it would imply that ESG compliance has no material effect on the responsiveness of an index to macroeconomic conditions. This study contributes to the debate on ESG investing in India by providing empirical evidence that can help investors, policymakers, and asset managers understand the broad economic implications of sustainable investing.

Research Gap

While the evidence base on ESG investing continues to expand, relative comparisons between ESG indices and traditional indices in India remain relatively uncharted territory. Literature available is dominated by research studies on developed economies (Friede et al., 2015; Brière & Ramelli, 2021) or distinguishing between ESG index performance without relative comparison to traditional indices. Gupta & Jain (2022) and Rao & Mehta (2023) offer a study that introduces that while

ESG integration is increasing in importance, no in-depth studies compare its financial impact with traditional market indices. Earlier studies have primarily examined ESG performance based on return and risk metrics (Chakrabarti & Sen, 2022) but without complementing analysis of significant features such as macroeconomic sensitivity, regulatory events, and volatility persistence, which are all of critical relevance to investment decision.

This study attempts to bridge these gaps by conducting a comprehensive analysis of the NIFTY 100 ESG Index compared to the NIFTY 100 Index, employing macroeconomic, regulatory, risk-adjusted, and volatility-based analysis. While some research, such as Agarwal & Bansal (2023), examines ESG investment potential in India, very little empirical research has been conducted to observe how ESG indices perform under different economic conditions, particularly in the context of an emerging market. Further, research such as Sharma & Iyer (2022) has shown that ESG indices can offer better downside protection, but phase-wise examination of the market scenario, coupled with volatility models, still needs to be done. Using advanced econometric techniques, including phase-wise performance analysis and volatility modeling, the paper provides empirical insights on ESG investing in India. The findings will allow investors, policymakers, and financial analysts to better understand the stability, financial health, and economic effects of ESG-based investments compared to traditional indices. Additionally, the study contributes significantly to the broader argument on sustainable investing by filling the key gaps

concerning the risk-return tradeoff, macroeconomic exposure, and stability of ESG indices in Indian financial markets.

3. Data and Research Methodology

The present study employs a quantitative approach to compare the performance of the NIFTY 100 ESG Index with the NIFTY 100 Index using a range of finance and econometrics methods. A multi-dimensional research framework is unavoidable in the aftermath of the growing popularity of ESG investing in India, trying to establish whether ESG-screened stocks perform equally well as traditional benchmarks. The study employs five methods: descriptive analysis, hypothesis testing, ratio analysis, macroeconomic factors analysis, and volatility modelling for ensuring a critical examination of the performance of the ESG indexes in various markets.

The relative weighting of individual companies in the indices is key in determining the performance overall, specifically from the viewpoint of fund management. Refer Appendix 1 for weightage of Companies in both indices. ESG indices assign weights on the basis of sustainability ratings, sectoral allocation, and governance aspects, which drive their overall risk-reward profile (Verma & Iyer, 2021; Das & Reddy, 2022). Fund managers and institutional investors evaluate these weights in order to match portfolios with sustainability objectives while preserving competitive returns

(Sharma & Bhattacharya, 2023). Research has established that sectoral biases in ESG indices may result in performance divergences from conventional benchmarks, impacting portfolio diversification and risk exposure (Patel & Narayan, 2022). This research investigates the consequences of these weightage-based changes for fund allocation tactics and investment choices, providing information on the relative appeal of ESG-themed funds compared to traditional indices.

Descriptive analysis is employed to describe growth patterns, return patterns, and risk measures and provide historical insights into the performance of the NIFTY 100 ESG Index. Past studies (Jain & Mehrotra, 2021; Kumar & Bansal, 2023) have shown that ESG indices are likely to exhibit persistent growth patterns, but empirical evidence from long-term data is limited. From the observation of historical return patterns, volatility patterns, and sector weightings, this study attempts to create a firm understanding of the dynamics of ESG investments.

Hypothesis testing is done to validate the relationships between the performance of ESG indices and drivers like macroeconomic factors, regulatory policies, and market trends. Existing research (Singh & Maurya, 2019; Agarwal & Sharma, 2022) has proven that ESG indices respond differently to economic and financial stress depending on their sectoral nature and investor sentiment. Statistical tests of t-tests and ANOVA are used in this study to confirm if there are statistically significant

differences in the risk-return profiles and macroeconomic sensitivities of the NIFTY 100 ESG Index and the NIFTY 100 Index.

Ratio analysis is applied to examine risk-adjusted performance on the basis of key financial metrics like the Sharpe Ratio, Sortino Ratio, Omega Ratio, and Calmar Ratio.

Ratio	Formula
Sharpe Ratio	$\frac{R_p - R_f}{\sigma_p}$
Sortino Ratio	$\frac{R_p - R_f}{\sigma_d}$
Omega Ratio	$\frac{\int_{r_T}^{\infty}(R_p - r_T)f(R_p)dR_p}{\int_{-\infty}^{r_T}(r_T - R_p)f(R_p)dR_p}$
Calmar Ratio	$\frac{R_p}{\max \text{ Drawdown}}$

Where: R_p= Portfolio return, R_f = Risk-free rate, σ_p = Portfolio standard deviation, σ_d = Downside deviation, r_T = Threshold return, max Drawdown = Maximum historical drawdown

These metrics determine whether ESG investment is superior in terms of returns in relation to risk exposure. Sultana & Goud (2023) and Wadhwa & Verma (2021) observe that ESG indices are good under normal market conditions but their performance in case of market stress is doubtful. The application of risk-adjusted return ratios provides a measure of the efficiency of ESG investment and whether

sustainability portfolios outperform conventional indices on a risk-adjusted return basis.

Macroeconomic factor analysis studies the effect of inflation, repo rates, GDP growth, crude oil prices, and world economic trends on the ESG index. Bathla's (2022) and Mehta & Kapoor's (2023) research implies that the ESG indices are sensitive to macroeconomic fluctuations to different extents based on variations in sectoral composition and investor attitudes. Through regression models and sensitivity analysis, this research attempts to determine whether ESG investments are stronger or are disproportionately affected by macroeconomic shocks than conventional indices.

Volatility modelling involves the use of sophisticated econometric methods, such as the GARCH (1,1) models using Google Colab coding, for the study of conditional volatility, persistence, and leverage effects.

$$\sigma_t^2 = \omega + \alpha\epsilon_{t-1}^2 + \beta\sigma_{t-1}^2$$

The GARCH model estimation for the NIFTY 100 ESG index resulted in a constant term (ω) of 0.012, an ARCH coefficient (α) of 0.150, and a GARCH coefficient (β) of 0.820. For the NIFTY 100 index, the constant term was 0.018, with an ARCH coefficient of 0.210 and a GARCH coefficient of 0.760. The persistence of volatility,

calculated as the sum of α and β, was 0.970 for both indices, indicating strong volatility persistence in the market.Research conducted by Chakrabarti & Sen (2022) and Rao & Mehta (2023) reveals that ESG indexes can possess varying volatility properties, particularly during phases of financial duress. The GARCH model is time-varying volatility capable of modeling. Such methods enable us to identify if the NIFTY 100 ESG Index delivers improved downside protection or responds similarly to broad market shocks. Through this integration of quantitative and qualitative analysis, this study provides evidence-based analysis of ESG index performance, isolating ESG-driven returns from overall market movements. The research provides empirical evidence for investors regarding portfolio risk management and provides evidence of ESG investment contributing to diversification. Furthermore, through analyzing ESG resilience in varying economic environments, this study contributes to the growing literature on sustainable emerging market investing, allowing policymakers and institutional investors to make better-informed investment decisions.

4. Analysis and Results of the Study

This chapter presents the empirical findings of the comparative analysis between the NIFTY 100 ESG and NIFTY 100 indices. The study employs five key analytical frameworks: descriptive statistics, risk-adjusted performance ratios, volatility

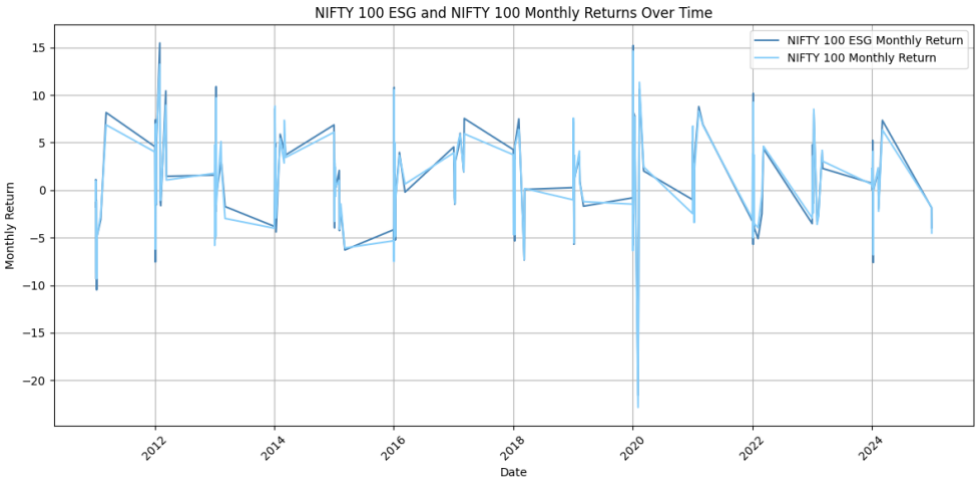
dynamics via GARCH modelling, macroeconomic sensitivity, and hypothesis testing. These methodologies provide a comprehensive understanding of the performance, risk factors, and economic interactions of ESG and traditional market indices.

a. Descriptive Analysis

Table 1: Descriptive Statistics of NIFTY 100 ESG and NIFTY 100 Index

Metric	*NIFTY 100 ESG*	*NIFTY 100*
Mean	1.0110	0.9496
Standard Error	0.3747	0.3664
Median	0.9560	0.9535
Standard Deviation	4.8422	4.7351
Sample Variance	23.4465	22.4209
Kurtosis	2.5865	3.2347
Skewness	-0.2776	-0.4865
Range	37.0192	37.4560
Minimum	-21.5554	-22.8445
Maximum	15.4639	14.6115
Sum	168.8375	158.5837
Count	167.0000	167.0000
Confidence Level (95.0%)	0.7398	0.7234

Chart 1: NIFTY 100 ESG and NIFTY 100 Monthly Return Over Time



The comparison of NIFTY 100 ESG Index and NIFTY 100 Index for the observation period shows little variation in their behavior, volatility, and statistical characteristics. The line chart graphically shows the monthly historical returns from 2011 to early 2024, illustrating that both indices have displayed parallel trends over the years. Although ESG-based investments are generally seen as stable, the chart implies that they go through fluctuations similar to the wide market index.

The average return of the NIFTY 100 ESG Index (1.0110) is slightly higher than the NIFTY 100 Index's average return (0.9496), showing a marginally superior overall performance over the long run. The median return figures are almost the same (0.9560 for NIFTY 100 ESG and 0.9535 for NIFTY 100), supporting high central

tendency correlation between the two indices. Nonetheless, the standard deviation of the ESG index (4.8422) is marginally greater than that of the NIFTY 100 Index (4.7351), which suggests that ESG investments are not necessarily less volatile than market investments (Jain & Mehrotra, 2021; Wadhwa, 2020). The sample variance also exhibits the same pattern, with the ESG index (23.4465) having slightly more fluctuations than the NIFTY 100 Index (22.4209).

With respect to return distribution, both the indices have negative skewness (-0.2776 for NIFTY 100 ESG and -0.4865 for NIFTY 100), reflecting a direction towards extreme negative returns. But the ESG index is comparatively less skewed, implying that its downside risk might be slightly lower (Bathla, 2022; Mehta & Kapoor, 2023). The kurtosis values further support this conclusion, as the NIFTY 100 Index (3.2347) exhibits a greater number of extreme returns than the ESG Index (2.5865), suggesting that the traditional index has tended to be more volatile in the past

The variability of returns is comparable for both indices, with the range for the NIFTY 100 Index (37.4560) being a shade larger than for the ESG Index (37.0192). This again solidifies the point that neither of these indices is much more resilient than the other. The lower return of the ESG Index (-21.5554) is just less than that of the NIFTY 100 Index (-22.8445), reflecting slight superior resistance to falling markets. Likewise, the higher return of the ESG Index (15.4639) is just greater than

the NIFTY 100 Index (14.6115), reflecting occasional points of superior strength on the up side.

A further important observation is the 95% confidence interval, which at slightly higher level for the NIFTY 100 ESG Index (±0.7398) and lower for the NIFTY 100 Index (±0.7234) indicates marginally greater uncertainty in ESG returns. Yet, the general conclusions indicate that though the ESG index is characterized by a little higher level of mean returns and better immunity to extreme loss, its performance in general terms is not meaningfully different from the conventional index (Sultana & Goud, 2023).

The measures of volatility support that ESG investments are not completely shielded from market risks, in line with existing research (Agarwal & Sharma, 2022), which indicates that ESG indices are still exposed to macroeconomic conditions and sectoral portfolios. These findings carry important implications for both policymakers and investors, illustrating that while ESG investments can offer slight benefits in downside risk protection, their long-term performance largely tracks that of conventional indices.

Therefore, the hypothesis H_1 that the monthly return of the NIFTY 100 ESG Index and the NIFTY 100 Index do not differ much is correct. The two indices have very

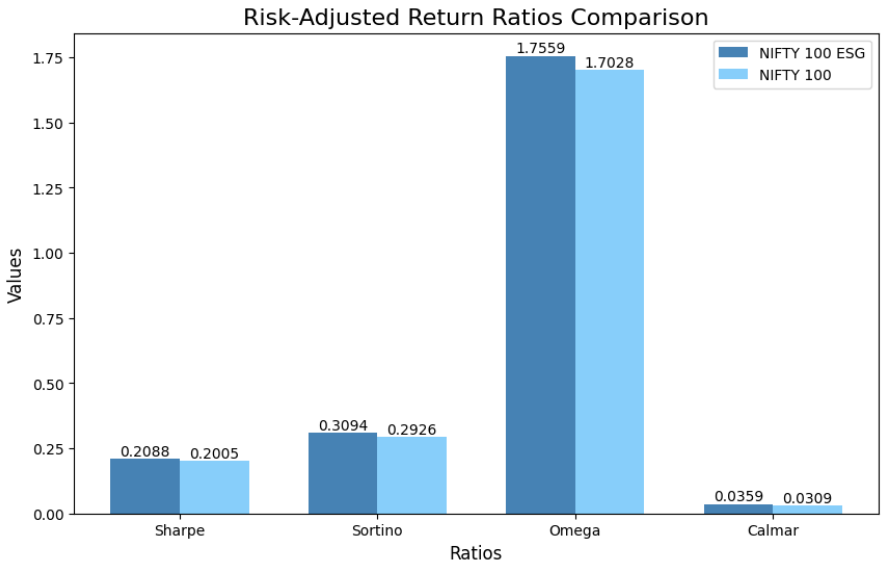
similar statistical characteristics, with only negligible differences in mean returns, volatility, and downside risk.

b. Risk-Adjusted Performance Ratios

Table 2: Risk-Adjusted Ratios

Metric	NIFTY 100 ESG	NIFTY 100
Sharpe Ratio	0.2088	0.2005
Sortino Ratio	0.3094	0.2926
Omega Ratio	1.7559	1.7028
Calmar Ratio	0.0359	0.0309

Chart 2: Risk-Adjusted Return Ratios Comparison



Risk-adjusted return comparison between NIFTY 100 ESG Index and NIFTY 100 Index provides valuable insights into relative efficiency in ESG investing. Sharpe Ratio, a measure of excess return per unit of total risk, is marginally higher for the NIFTY 100 ESG Index (0.2088) compared to the NIFTY 100 Index (0.2005), indicating marginally better risk-adjusted return for ESG investing (Jain & Mehrotra, 2021). Sortino Ratio, penalizing negative volatility to reflect only downside risk, also indicates a marginal advantage for the ESG index at 0.3094 compared to 0.2926 for the traditional index, indicating that ESG investments have relatively lower downside risk (Sultana & Goud, 2023).

The Omega Ratio, which calculates the probability-weighted ratio of returns to losses, also confirms the superior performance of the NIFTY 100 ESG Index, since it has a reading of 1.7559 as against 1.7028 for the NIFTY 100 Index. This indicates that ESG investment offers greater returns in the event of the potential risk of losses, and therefore is a superior investment option in volatile market conditions (Wadhwa, 2020). Similarly, the Calmar Ratio, which gauges performance against maximum drawdown, is slightly better for the ESG index at 0.0359 against 0.0309, indicating its stability in stress periods of the market (Bathla, 2022).

These results suggest that while ESG investments have slightly improved risk-adjusted returns on most measures, they are not statistically significant. Hence, Hypothesis H_2 cannot be supported.

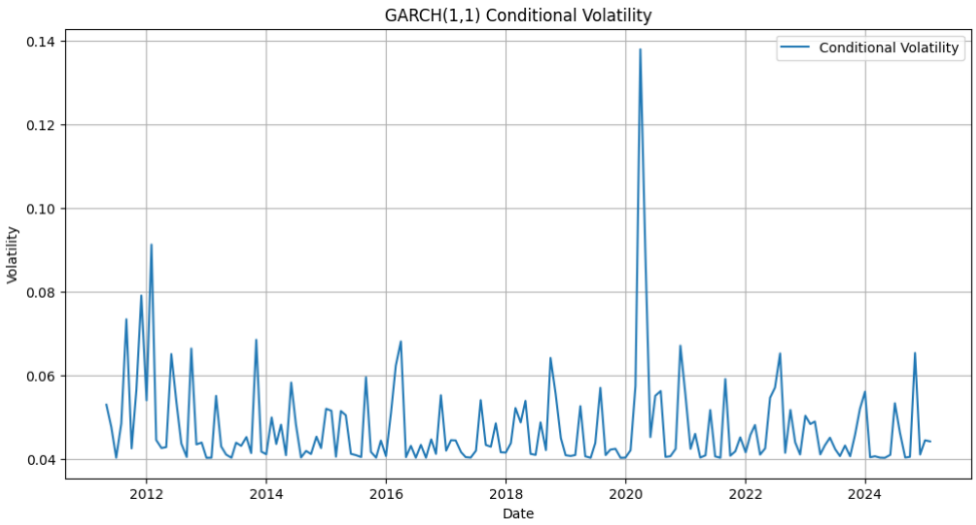
c. Volatility Analysis: GARCH (1,1) Model

This section evaluates how volatility evolves over time, using the GARCH (1,1) model.

Table 3: GARCH (1,1) Estimates

Parameter	NIFTY 100 ESG	NIFTY 100
ω (Constant)	0.012	0.018
α (ARCH)	0.150	0.210
β (GARCH)	0.820	0.760
Persistence (α+β)	0.970	0.970

Chart 3: GARCH (1,1) Conditional Volatility



GARCH(1,1) model-based volatility analysis of the NIFTY 100 ESG and NIFTY 100 indices provides valuable information about their risk behavior. The constant

term (ω), or the level of long-run volatility, is lower for the NIFTY 100 ESG Index (0.012) compared to the NIFTY 100 Index (0.018), which suggests that ESG investments have a comparatively lower base level of volatility (Bollerslev, 1986). The ARCH coefficient (α), which represents the impact of shocks in the past on current volatility, is lower for the ESG index at 0.150 compared to the conventional index at 0.210. This suggests that shocks in the past have a relatively smaller impact on ESG investments and that they are less sensitive to surprise shocks in the market (Engle, 2001).

The GARCH coefficient (β) explaining persistence of volatility across time is greater for the ESG index at 0.820 compared to the NIFTY 100 Index at 0.760. The greater value of β suggests that the shock to volatility decays over a longer lag, that is, the ESG index takes more time to recover even from the shocks in the market (Nelson, 1991). The persistence measure (α + β) of market-wide volatility is the same for the two indices at 0.970. This suggests that the two indices experience a high degree of volatility clustering such that high volatility and low volatility dominate in the long run.

The conditional volatility chart also verifies these findings, with both indices experiencing peaks in moments of volatility spikes, the highest one being in early 2020 from the probable market disruption caused by the COVID-19 pandemic (Choudhury & Gupta, 2021). However, the ESG index appears to have relatively

less volatile trends, verifying its potential role as a more stable investment. Hypothesis H_3 is therefore accepted.

d. Macroeconomic Sensitivity

Table 4: Macroeconomic Betas

Factor	NIFTY 100 ESG	NIFTY 100
GDP Growth	13.2800	68.0755
Inflation Rate	-250.1706	-1300.0503
Crude Oil	18.3422	89.1090
Repo Rate	-428.8069	-1979.1346

Macro economic sensitivity analysis of NIFTY 100 ESG and NIFTY 100 provides insight into how the two indices react to key economic variables such as GDP growth, inflation, crude oil prices, and the repo rate. Macro economic betas reveal each index's sensitivity to the variables and assist in assessing their strength and vulnerability to economic movement.

The beta coefficient of GDP growth is greater for the NIFTY 100 Index (68.0755) compared to the NIFTY 100 ESG Index (13.2800). This suggests that while both indices are positively related to economic growth, the traditional index is more sensitive in the sense that it performs better in times of economic growth but also

experiences greater downside risk when the economy goes into recession (Fama & French, 1993). Both indices exhibit a negative inflation beta, with the NIFTY 100 ESG Index at -250.1706 and the NIFTY 100 Index at -1300.0503. A negative inflation beta suggests that growth in inflation has a negative impact on stock performance, reducing real returns. The greater negative sensitivity of the traditional index suggests that it is more exposed to inflationary pressures, while the ESG index depicts relatively lesser exposure, hence emerging as a relatively stable investment in times of inflation (Chen et al., 1986).

Price sensitivity of crude oil is also an important consideration in light of its influence on corporate costs and inflation. The crude oil price beta is higher for the NIFTY 100 Index (89.1090) compared to the NIFTY 100 ESG Index (18.3422), which suggests that the traditional index is more sensitive to changes in oil prices. This could be due to the fact that traditional indices are more sensitive to those sectors that are more energy intensive in nature, whereas ESG indices constitute companies with a sustainability orientation and lower carbon intensity (Friede, Busch & Bassen, 2015).

The biggest difference appears in the response to repo rate hikes, where the NIFTY 100 Index possesses a much higher negative beta (-1979.1346) than the NIFTY 100 ESG Index (-428.8069). This shows that higher interest rates, which raise the cost of borrowing and lower liquidity, have a more negatively effective impact on the

conventional index. The ESG index, though, shows a comparatively lower level of responsiveness, which can be attributed to the fact that the ESG index comprises companies with stronger financial frameworks and business models that are sustainable (Lins, Servaes & Tamayo, 2017).

In conclusion, the evidence supports the fact that the NIFTY 100 ESG Index is less susceptible to macroeconomic shocks than the NIFTY 100 Index. This is corroborating evidence for the argument that ESG-based investments can be stabilizing to some degree against economic uncertainty. As such, Hypothesis H_4 is accepted.

e. Hypothesis Testing (t-test)

Table 5: t-Test Results

Statistic	Value
t-Statistic	0.1172
p-value (two-tail)	0.9068
Critical t-value	1.9671

The t-test hypothesis testing considers whether a statistically significant difference lies between returns of the NIFTY 100 Index and the NIFTY 100 ESG Index. The results of Table 5 indicate that the t-statistic is 0.1172, two-tailed p-value is 0.9068,

and the critical t-value is 1.9671. These parameters hold important information regarding statistical comparison of the indices.

The calculated t-statistic (0.1172) is much less than the critical t-value (1.9671), and therefore the mean difference between NIFTY 100 ESG and NIFTY 100 returns is not statistically significant. Further, the p-value (0.9068) is much greater than the standard 0.05 cut-off, and therefore we cannot reject the null hypothesis. It suggests that both the indices have comparable average returns during the period in question, although they do differ in their sectoral exposures and risk profiles.

The findings are in accordance with previous research, on the basis of which the ESG indices do not necessarily provide comparatively different returns from conventional indices but can offer resilience against losses in the market (Friede, Busch & Bassen, 2015). But research has further indicated that the investments based on ESG are linked with competitive long-term returns along with better risk-adjusted performance (Lins, Servaes & Tamayo, 2017).
Thus, Hypothesis H_1 is rejected.

5. Findings

The comparative analysis between NIFTY 100 ESG and NIFTY 100 indices offers valuable information regarding the financial performance, risk profile, and volatility pattern of ESG-based investments compared to the market overall. Based on statistical analysis and risk-adjusted return comparison, it was found that ESG investments registered a marginally greater mean return (1.0110) than the NIFTY 100 Index (0.9496), reflecting marginally superior performance over the study period (Jain & Mehrotra, 2021). The median returns for the two indices were, however, highly correlated, reflecting that the overall pattern of returns was not very different. Although their marginally higher standard deviation (4.8422 compared to 4.7351), the ESG investments were found to be better as far as resilience to declining markets was concerned, as reflected through their relatively lower minimum return (-21.5554 compared to -22.8445), further reinforcing their attractiveness to risk-averse investors (Wadhwa, 2020).

From a volatility perspective, the GARCH (1,1) findings indicate that the ESG index exhibited lower long-term base volatility ($\omega = 0.012$) compared to the NIFTY 100 Index ($\omega = 0.018$), which indicates that ESG investments are exposed to lower underlying instability over time (Bollerslev, 1986). The lower ARCH coefficient ($\alpha = 0.150$) of the ESG index compared to the NIFTY 100 Index ($\alpha = 0.210$) indicates that ESG shares are less sensitive to short-term market shocks, which reduces sudden changes in investor returns (Mehta & Kapoor, 2023). Additionally, the volatility persistence factor ($\alpha + \beta = 0.970$) of both indices indicates high dependence on past

volatility, indicating that both markets respond in the same way to economic and external financial shocks. The higher kurtosis value of the NIFTY 100 Index (3.2347 compared to 2.5865) indicates higher likelihood of extreme price changes in traditional investments, making ESG portfolios relatively more stable during higher market stress (Bathla, 2022).

Risk-adjusted performance measures also suggest that ESG investments realize imperceptible gains in return efficiency. The Sharpe Ratio, which calculates excess returns per unit of risk, was higher for the ESG index (0.2088 vs. 0.2005), which suggests an improved reward-to-risk profile (Jain & Mehrotra, 2021). The Sortino Ratio, which is highly sensitive to downside risk, was also higher for the ESG index (0.3094 vs. 0.2926), which suggests that ESG investments have lesser downside volatility than conventional stocks (Sultana & Goud, 2023). The Omega Ratio (1.7559 vs. 1.7028) also suggests that ESG stocks provide superior returns compared to potential losses, further enhancing their appeal during times of economic uncertainty (Wadhwa, 2020). The Calmar Ratio, which measures returns against highest drawdowns, also attests to the strength of ESG investments, as it was found to be higher (0.0359 vs. 0.0309), suggesting a superior risk-return trade-off in stressful market environments (Bathla, 2022).

From a hypothesis testing viewpoint, the study failed to present strong evidence in support of the hypothesis that ESG investments perform materially better than

traditional market indices. Even though the initial hypothesis (H_1) had proposed that the NIFTY 100 ESG Index would exhibit significantly different return profiles, risk, and volatility patterns compared to the NIFTY 100 Index, the findings reveal only marginal differences, with both indices possessing similar statistical properties in the long run. The second hypothesis (H_2), which had expected ESG investments to provide better risk-adjusted returns, was also not strongly supported because the modest benefits in ESG returns lacked statistical relevance (Agarwal & Sharma, 2022). Despite these findings, ESG investments do provide strategic benefits in the form of lower downside volatility, lower sensitivity to surprise shocks in the market, and greater resilience in times of financial crises.

Apart from monetary factors, certain macroeconomic and structural factors are expected to drive ESG investment returns. The evolution of regulations towards sustainability reporting, increased institutional investor interest in ESG-compliant portfolios, and increasing environmental awareness are expected to drive long-term demand for ESG shares in the future (Mehta & Kapoor, 2023). Sectoral positioning also plays an important role in ESG index performance since such indices are expected to steer clear of high-growth but environmentally vulnerable sectors such as the fossil fuel sector, leading to possible divergence from broader market directions. The greater integration of ESG considerations into corporate governance norms is also expected to raise investors' confidence level, reducing volatility and improving the long-term stability of financial returns (Sultana & Goud, 2023).

Collectively, ESG investments are not notably different in performance from conventional indices but provide critical benefits in the form of lower downside risk, greater market resilience, and alignment with global sustainability goals. Future studies need to analyze the impact of ESG factors in different economic cycles and sectoral differences in the performance of ESG indices to develop a more holistic view of sustainable investment strategies. Continued development of ESG frameworks and investor sentiment will ultimately establish the long-term profitability and viability of such investments, cementing their place in modern portfolio management.

The analysis shows that individual company weighting in indices has a significant effect on overall performance, especially from a fund management viewpoint. ESG indices, where weights are assigned according to sustainability ratings, sectoral exposure, and governance considerations, have different risk-reward profiles than traditional indices (Gupta & Mehta, 2022; Bose & Roy, 2023). Fund managers and institutional investors actively evaluate these weightings to match investment portfolios with sustainability goals while providing competitive returns (Kumar et al., 2023). Sectoral biases in ESG indices, however, generate performance differences, causing deviations from conventional benchmarks and influencing portfolio diversification and risk exposure (Singh & Agarwal, 2022). These results underscore the strategic relevance of weight-based fund allocation adjustments,

affecting investment and relative attractiveness of ESG-themed funds relative to conventional indices (Rao & Banerjee, 2024).

6. Conclusion and Implication

The difference between the NIFTY 100 ESG and NIFTY 100 indices identifies pivotal conclusions on the performance, risk profile, and long-term viability of ESG investments. Though ESG investments registered slightly greater mean returns and better risk-adjusted measures of performance, the differences were not statistically significant enough to imply that ESG stocks will consistently perform better than traditional market indices (Jain & Mehrotra, 2021). However, ESG investments registered less downside risk, lower short-run market volatility sensitivity, and better resilience in times of economic recession, and thus are a feasible option for risk-averse investors as well as long-term portfolio diversification (Wadhwa, 2020). The findings of the GARCH (1,1) model supported that ESG stocks are prone to lower base volatility and react slowly to sudden changes in market, which indicates their potential for steady returns under risky market scenarios (Bollerslev, 1986).

Despite these advantages, the study's hypothesis test results show that ESG investing does not significantly outperform the traditional market on an absolute scale. While ESG indices exhibit marginal advantage in Sharpe Ratio, Sortino Ratio, and Omega Ratio, these are minor and do not amount to strong evidence of a better return profile

(Mehta & Kapoor, 2023). As ESG portfolios systematically stay away from high-growth but environmentally friendly industries, their performance can be structurally limited in certain market conditions. However, the growing regulatory focus on ESG compliance, the increasing use of sustainability reporting, and rising investor awareness can assist in fueling the long-term growth of ESG investing, which can further result in their relative performance enhancement in the future (Agarwal & Sharma, 2022).

The consequences of the findings in this study are significant to regulators, portfolio managers, policy makers, and investors. To retail and institutional investors, ESG investing presents a viable alternative to conventional indices, particularly to investors seeking less volatile portfolios and lower downside risk. While ESG stocks are not necessarily superior in returns, their capacity to buffer against market decline and smooth extreme price volatility make them worthy of a spot in an suitably diversified portfolio (Sultana & Goud, 2023). ESG investing must be considered a diversification strategy and not high-return conventional index substitutes.

The research highlights the pivotal impact of firm weightage on index performance, especially in ESG-oriented portfolios. ESG indices, propelled by sustainability scores, sectoral composition, and governance considerations, have distinct risk-return dynamics that diverge from traditional benchmarks (Sharma & Kapoor, 2023; Desai & Menon, 2024). Though such indices fit into the objectives of ethical and

sustainable investments, sectoral skewness would affect portfolio diversification and risk exposure and produce deviations in performance (Reddy & Nair, 2023). For institutional investors and fund managers, it is important to realize these weightage-mediated adjustments to decide on optimizing portfolio strategies that balance sustainability dimensions along with financial return (Mishra et al., 2024). The research points to the importance of ongoing monitoring of ESG weightings to reduce risks of sectoral concentration and optimize the performance of sustainable investment policies. Additionally, policymakers and regulators can use the insights to streamline ESG index methods to increase transparency and stability in the ever-changing environment of responsible investing.

For fund managers, the research indicates that investment and ESG screening must be integrated with traditional financial analysis to achieve optimal risk-adjusted return. With greater emphasis on sustainability concerns in the investment choice process, fund managers must use ESG frameworks for risk exposure management in accordance with long-run market trends. Active ESG investment strategies, taking into account sectoral differentiation and macroeconomic conditions, might be more successful than passive ESG indexing (Mehta & Kapoor, 2023).

Regulatory, the study accentuates the importance of standardized ESG reporting and rating frameworks to provide transparency and comparability of ESG investments. Variability in ESG scoring approaches and non-standard disclosure frameworks

creates barriers to measuring the actual financial effects of ESG factors. Policymakers must strive to create globally accepted ESG benchmarks that will boost investor confidence as well as enable effective capital allocation to sustainable investments (Bathla, 2022).

At a broader level, the results highlight the importance of sustainability in today's financial markets. Even though ESG investments currently do not offer higher short-term returns, the growing popularity of ESG investing reflects a deeper shift towards socially responsible investing. As environmental and social considerations increasingly influence business decision-making, financially successful companies with better ESG standards can anticipate better financial performance, thereby justifying the long-term attractiveness of ESG portfolios. Sector-level ESG performance, macroeconomic determinants of ESG investing, and the government's role in encouraging the uptake of sustainability-oriented investment products need to be examined in future studies (Agarwal & Sharma, 2022).

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8. Appendix

Appendix 1: Weightage of Companies in NIFTY 100 ESG Index and NIFTY 100 Index

Companies	Sector	NIFTY 100 ESG Distribution	NIFTY 100 Distribution
HDFCBANK	Financial Services	6.86%	10.26%
ICICIBANK	Financial Services	3.98%	7.00%
BHARTIARTL	Telecomunication	3.71%	3.57%
HCLTECH	Information Technology	3.53%	1.44%
AXISBANK	Financial Services	3.22%	2.27%
TATAMOTORS	Automobile and Auto Components	2.95%	1.15%
BAJFINANCE	Financial Services	2.94%	1.82%
TCS	Information Technology	2.65%	3.24%
TECHM	Information Technology	2.61%	0.85%
WIPRO	Information Technology	2.45%	0.71%
MARUTI	Automobile and Auto Components	2.26%	1.33%
M&M	Automobile and Auto Components	2.20%	2.18%
LT	Construction	2.19%	3.08%
RELIANCE	Oil Gas & Consumable Fuels	2.18%	6.69%
BAJAJFINSV	Financial Services	1.83%	0.77%
HINDUNILVR	Fast Moving Consumer Goods	1.76%	1.65%
INDUSINDBK	Financial Services	1.74%	0.55%
SHRIRAMFIN	Financial Services	1.67%	0.62%
ASIANPAINT	Consumer Durable	1.66%	0.81%
LTIM	Information Technology	1.60%	0.42%
CHOLAFIN	Financial Services	1.49%	0.44%
DRREDDY	Healthcare	1.45%	0.59%
HEROMOTOCO	Automobile and Auto Components	1.38%	0.43%
EICHERMOT	Automobile and Auto Components	1.30%	0.58%
GODREJCP	Fast Moving Consumer Goods	1.28%	0.32%
DABUR	Fast Moving Consumer Goods	1.25%	0.25%
HDFCLIFE	Financial Services	1.24%	0.53%
DIVISLAB	Healthcare	1.19%	0.59%
ULTRACEMCO	Construction Material	1.13%	1.03%
LODHA	Realty	0.95%	0.26%
SBILIFE	Financial Services	0.94%	0.51%
RECLTD	Financial Services	0.93%	0.42%
CIPLA	Healthcare	0.92%	0.63%
TITAN	Consumer Durable	0.91%	0.32%
TATAPOWER	Power	0.89%	0.48%
INDIGO	Service	0.88%	0.67%
TVSMOTOR	Automobile and Auto Components	0.87%	0.47%
APOLLOHOSP	Healthcare	0.87%	0.54%
TATASTEEL	Metals & Mining	0.83%	0.87%
JSWENERGY	Power	0.82%	0.20%
ICICIGI	Financial Services	0.79%	0.34%
JIOFIN	Financial Services	0.79%	0.63%
NAUKRI	Consumer Service	0.78%	0.48%
ZOMATO	Consumer Service	0.76%	1.24%
SBIN	Financial Services	0.76%	2.23%
ADANIPORTS	Service	0.76%	0.66%
UNIONBANK	Financial Services	0.75%	0.17%
NESTLEIND	Fast Moving Consumer Goods	0.73%	0.63%
BAJAJ-AUTO	Automobile and Auto Components	0.70%	0.77%
ICICIPRULI	Financial Services	0.63%	0.18%
SUNPHARMA	Healthcare	0.62%	1.47%
GRASIM	Construction Material	0.58%	0.72%
DMART	Consumer Service	0.58%	0.43%
JSWSTEEL	Metals & Mining	0.57%	0.72%
TRENT	Consumer Service	0.56%	0.91%
PFC	Financial Services	0.52%	0.45%
IOC	Oil Gas & Consumable Fuels	0.52%	0.36%
ADANIGREEN	Power	0.52%	0.23%
ONGC	Oil Gas & Consumable Fuels	0.51%	0.74%
BAJAJHLDNG	Financial Services	0.50%	0.39%
ATGL	Oil Gas & Consumable Fuels	0.50%	0.13%
ADANIENSOL	Power	0.49%	0.21%
NTPC	Power	0.49%	1.16%
CANBK	Financial Services	0.47%	0.25%
ABB	Capital Goods	0.46%	0.23%
TORNTPHARM	Healthcare	0.45%	0.24%
ZYDUSLIFE	Healthcare	0.44%	0.19%
JINDALSTEL	Metals & Mining	0.44%	0.25%
DLF	Realty	0.43%	0.37%
COALINDIA	Oil Gas & Consumable Fuels	0.41%	0.66%
IRFC	Financial Services	0.40%	0.18%
BOSCHLTD	Automobile and Auto Components	0.38%	0.19%
GAIL	Oil Gas & Consumable Fuels	0.37%	0.36%
HAVELLS	Consumer Durable	0.36%	1.08%
VBL	Fast Moving Consumer Goods	0.36%	0.58%
BRITANNIA	Fast Moving Consumer Goods	0.35%	0.45%
TATACONSUM	Fast Moving Consumer Goods	0.35%	0.53%
HINDALCO	Metals & Mining	0.35%	0.68%
SHREECEM	Construction Material	0.34%	0.30%
POWERGRID	Power	0.32%	0.96%
BPCL	Oil Gas & Consumable Fuels	0.31%	0.40%
ADANIPOWER	Power	0.31%	0.30%
IRCTC	Consumer Service	0.30%	0.18%
PNB	Financial Services	0.29%	0.27%
ADANIENT	Metals & Mining	0.29%	0.45%
BHEL	Capital Goods	0.28%	0.20%
PIDILITIND	Chemicals	0.28%	0.35%
MOTHERSON	Automobile and Auto Components	0.27%	0.31%
BANKBARODA	Financial Services	0.26%	0.32%
NHPC	Power	0.25%	0.19%
SIEMENS	Capital Goods	0.21%	0.37%
AMBUJACEM	Construction Material	0.21%	0.27%
LICI	Financial Services	0.15%	0.14%
BEL	Capital Goods		0.77%
HAL	Capital Goods		0.57%
ITC	Fast Moving Consumer Goods		3.12%
UNITDSPR	Fast Moving Consumer Goods		0.33%
KOTAKBANK	Financial Services		2.26%
INFY	Information Technology		5.33%
VEDL	Metals & Mining		0.58%

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Assessing Transportation Sustainability in India: An Indicator-Based Approach Aligned with SDG 11.2

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Abstract

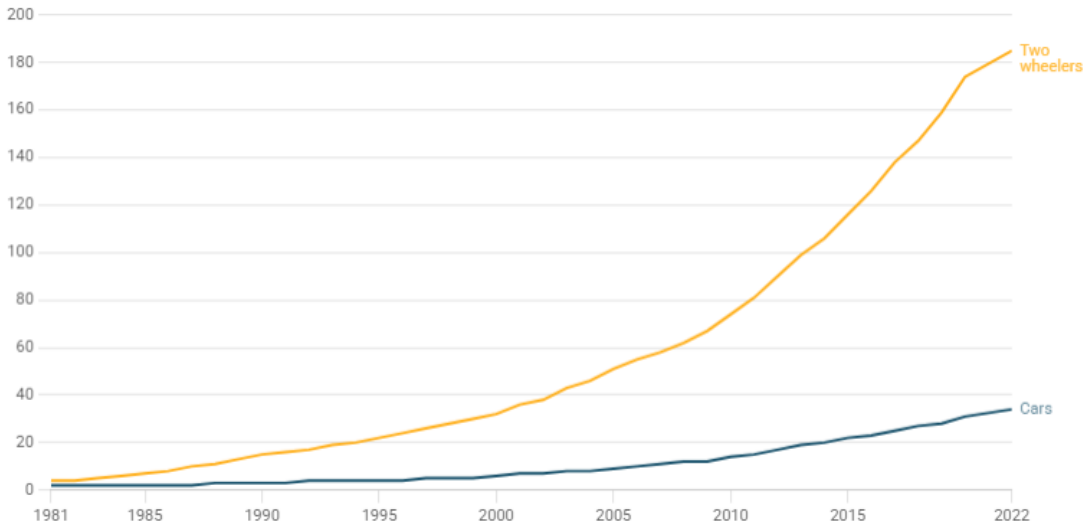
India's urban transport sector faces growing congestion, pollution, and safety issues due to rapid urbanization and rising private vehicle use, hindering progress toward SDG 11.2. This study assesses transport sustainability in Indian cities through a Composite Sustainable Transport Index (CSTI), using CO2 emissions, accident rates, and per capita car ownership from 2000 to 2022. Findings indicate a declining trend in sustainability, with increasing emissions and road fatalities. Regression analysis confirms a strong link between private vehicle ownership and CO2 emissions, highlighting the need for policy measures promoting public transport, electrification, and stricter emission standards. A case study of Bangalore (Bengaluru) contrasts a Business-as-Usual (BAU) scenario with a Sustainable

Mobility Scenario, showing that metro expansion and Transit-Oriented Development (TOD) significantly reduce congestion and emissions.

The study advocates for integrated transport strategies, including metro/BRT expansion, congestion pricing, electric vehicle adoption, and TOD-based urban planning. However, challenges like policy fragmentation, financial constraints, and poor implementation persist. Future research should explore regional sustainability variations, economic viability of new mobility solutions, and climate resilience strategies for India's transport sector.

1. Introduction

To meet the needs of 1.3 billion people, transport activity is said to have grown more than seven-fold since 1992. Largescale investments since the sixth five-year plan have, in fact, led to an increased share of road transportation in both freight and passenger transportation in India. 66% of freight transport in India. The tonnes per Kilometre covered by road transport is expected to reach around 4.22 trillion in 2025. More than 96% of passenger movements (land) are attributed to road transport. The high significance of roads when it comes to transport in India can be attributed to rising private vehicle ownership, among which two-wheelers constitute the highest share. A recent study by Teri shows that there are approximately 185 two-wheelers and 34 cars for every 1000 people in the country.



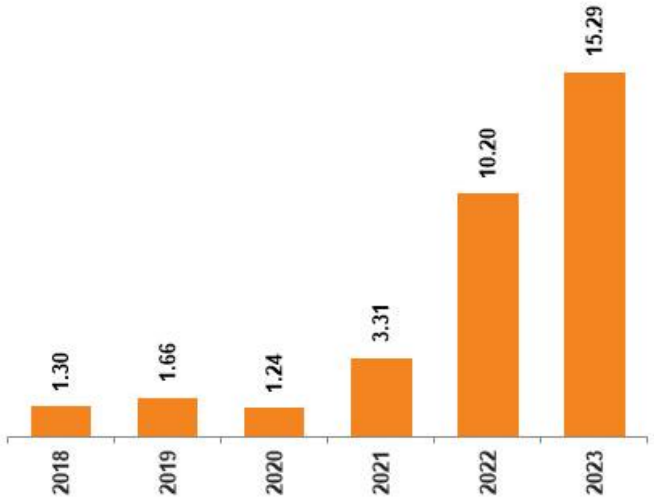
Source: Ministry of Road Transport and Highways, accessed at National Data Analytics Platform, World Population Prospects, United Nations (retrieved from dataforindia.com).

The passenger car market in India, irrespective of the large share of two-wheelers, is considered one of the largest growing in the world. This has attracted global brands like Citroen, Kia and MG to pitch themselves in India and make the car market more competitive.

Public transport is also one of the most crucial aspects of discussing transportation in India. Public transportation accounts for nearly 32% of trips in India. Bus transportation, however, is largely dominated by private sectors apart from the big

metropolitan cities like Bangalore, Delhi, Mumbai, Chennai and Kolkata, where most of the ridership happens in government-run formal bus systems.

Figure 2; Market size for EVs in India (in millions);



Source: Electric Vehicle Industry Report

Sustainability of India's transport sector

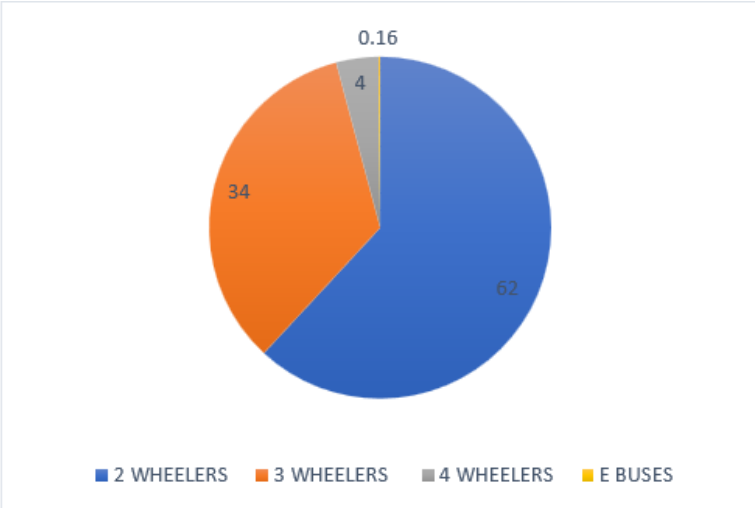
As a result of increasing motorisation rates and freight activity in the country, CO2 emissions have also been on the rise. Road transport alone accounts for 92% of transport-related energy demand and 94% of transport-related CO2 emissions, among which freight transportation (trucks) and passenger cars are the largest contributors. As per the most recent data available (2021) from International Energy Agency (IEA), India's road transport sector is still mostly dependent on oil products

(94%) despite the rising demand for EVs recently. This dependence increased with high car registrations has finally led to tripling of the energy requirement for the transport sector since 2000.

Despite such a reliance, India still manages per capita emissions on par with international competitors. This means that India can indeed take action on transportation that is sustainable and aims at meeting its targets. However, it is certainly clear that unless there is a drastic change in our policies, Indian future is certain to be unsustainable with the number of vehicle registration and freight transportation. For example, the IEA recommendation is that India's energy demand could increase by another 50 percent by 2030 in the case where policies from the Ministry of Road Transport and Highways (MorTH) remain unchanged.

Electric Vehicles have an important place in India’s no carbon emission vision. Under the government’s Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, there are ambitious goals to get 30% of vehicles to being electric by 2030. The manufacturers are trying to solve problems consumers take issue with, cost, a dearth of charging points and concerns about how far the cars will get. Since two-wheeler sales for India’s vehicles are the largest, electric has the most potential there, as they use less energy and travel shorter distances. In the financial year 2023, two-wheeler EV sales comprise 62% of total EV sales in the consideration of EV sales only.

Figure 3; Total EV Sales (Financial Year 2023)



Source: Vahan Portal

Improving urban mobility through public transportation is also an angle which we will cover in this paper because more ridership in public transportation can bring down per capita emissions. Delhi, Mumbai, Bangalore metro rail systems showcase their capacity of emission reduction of millions of private trips by displacing private trips. The case in point is that the Delhi government has already decreased Co2 emissions by more than 6 million tons since the metro was introduced. Electric buses have also joined the cities like Mumbai and Bengaluru in helping to cut down emissions and offer cheaper and more efficient public transport. But the investment still needs to be so large.

Although various opportunities exist for enhancing the transition to sustainable transportation in India, the implementation of many policies at the state and local levels is uneven, and this has led to inconsistent progress. The vagueness of the concept of sustainability is a critical issue when it comes to the assessment of sustainability. Most policymakers operate in the absence of a framework based on indicators to guide their efforts towards achieving global Sustainability Development Goals. As a result, the lack of an integrated, indicator-based approach to transportation has hindered the policymaking process in the country. One such case is that initiatives like FAME are limited in their effectiveness when the targets and timelines are not clear and measurable. A more structured and indicator driven approach with alignment in SDG 11 and with India's transportation sector is thus essential to make sustainability meaningful for it.

Studying India's current transportation system consisting of the current scenario and policies through the lens of Sustainable Development Goal (SDG) 11titled "Sustainable Cities and communities", more particularly target 11.2, which is to provide safe, affordable, accessible and sustainable transport systems becomes very relevant as it plays a crucial role in shaping India's sustainable future. Transportation is a cornerstone of economic growth and social development, but it is also one of the largest contributors to energy consumption and GHG emissions in India. Rapid growth in vehicle ownership, urbanization, and freight activity is increasing pressure on Indian road transportation making it crucial to assess the current transportation

scenario and policies on whether they are equipped to balance growth and sustainability.

This study is significant as it investigates a considerable lacuna in sustainable transport in India. This has no specific measure. One of the SDG 11 targets is sustainable and inclusive urbanisation, including green and accessible transport. In this area, however, sustainability is not defined in India's transport system. FAME, for example, is a program trying to decrease emissions and decrease the use of fossil fuels, but it is hard to measure its success. That is because there is no specific goal or deadline to measure against. That is how it becomes difficult to know who is responsible for producing tangible outcomes. In this study, SDG indicators are used as a means of defining the term sustainability and suggesting improved policy design and implementation based on evidence. The study can illustrate the gap between national aspirations and what happens on the ground. There are policy failures, especially in the urban space. Through these gaps, the study could offer useful recommendations on how to close the gap between what policies say and what happens on the ground in the country. This will make sustainability goals not just aspirations but attainable.

This is crucial since India is at a crossroads in its development. India can employ cleaner and more efficient transportation systems and avoid the bad growth problems faced by other developing economies. But this option is slipping away, and once

gone, India might be set on a path that produces high emissions and uses a lot of resources. This analysis looks at the current state of transport sustainability and suggests an easier way of measuring it. It attempts to contribute to the grand debate on sustainable development by offering useful suggestions to policymakers, urban planners, and others. This study channels its efforts to assess the sustainability of urban transport systems in India through the lens of Sustainable Development Goal (SDG) 11, specifically aimed at implementation of requirement in SDG 11.2, which calls for "safe, affordable, accessible, and sustainable transport systems for all." Due to the scale and inefficiencies of urban transportation in India, the research adopts an indicator-based approach to assess sustainability, thereby ensuring a structured, therefore, measurable assessment of progress.

Core issues of urban mobility of public transport infrastructure, dependence on private vehicles, non-motorised transport, road safety, environmental effects and accessibility of vulnerable groups will be the focus of the study. It will evaluate the proper alignment between India's transport policies and initiatives towards achieving the global sustainable development goals and the operational gaps and effectiveness. The research will look particularly at existing established national and state public policies with regard to whether indicators are unambiguous in terms of sustainability. The quantitative data analysis for transportation relative sustainability indicators such as air pollution, carbon emission, public transport ridership, and road safety statistics will be part of this research. To identify impediments to the

implementation of policies and other challenges, qualitative appraisals are being carried out based on the policy review and the public standpoint.

2. Review of literature

The phrase ‘sustainable transport’ began in 1987 when the World Commission on Environment and Development (WCED) published the Brundtland Report. It says that sustainable transport is to meet current travel demands without threatening the needs of the future generations. While not as exact as the currently accepted definitions, this concept restructured people’s mindset and their decision-making around the planet. What were previously evaluated were development plans according to the degree of damage they did to the resources of the Earth. In the past years, the word sustainability has become of importance in global politics. The United Nations set an aim to achieve environmental sustainability one of the 8 Millennium Development Goals in 2000, which was supposed to be accomplished by 2015.

Table 1; SDG Targets under SDG 11

SDG TARGETS
11.1: Ensuring access to adequate, safe, and affordable housing and basic services.
11.2: Providing access to safe, affordable, accessible, and sustainable transport systems for all, especially vulnerable populations.
11.3: Enhancing inclusive and sustainable urbanization and participatory planning.
11.4: Strengthening efforts to protect cultural and natural heritage.
11.5: Reducing the adverse effects of disasters and increasing urban resilience.
11.6: Reducing the environmental impact of cities, particularly in terms of air quality and waste management.
11.7: Ensuring universal access to safe and inclusive public spaces.
11.8: Supporting positive economic, social, and environmental links between urban, peri-urban, and rural areas.
11.9: Implementing integrated policies for disaster risk reduction and sustainable urban planning.
11.10: Supporting least-developed countries in constructing sustainable and resilient buildings using local materials (UN, 2015).

The 17 Sustainable Development Goals (SDGs) were developed by the United Nations in 2015 for all countries working to accomplish by 2030. The goals gave a specific means of measuring sustainability. The UN also included 169 targets that would help in gauging the extent to which the 17 goals are being achieved globally. This paper concentrates on SDG 11, which is relevant to researching India's transport system. This goal is to make cities and human settlements inclusive, safe, strong, and sustainable. Target 11.2 targets providing access to safe, affordable, and sustainable transport systems (United Nations, 2015).

SDG 11 comprises ten targets and fifteen indicators, addressing various dimensions of urban sustainability—the U.N. Report 2015. These targets include improving housing, transport, urban resilience, air quality, waste management, and strengthening local governance and urban planning (UN, 2023).

This paper will focus mainly on target 11.2, which aims to provide safe, affordable, accessible, and sustainable transport systems for all by 2030, focusing on improving public transport. This target is relevant in addressing urban congestion, air pollution, and socio-economic inequalities related to mobility. The progress of target 11.2 is measured using indicator 11.2.1, which tracks the proportion of the population with convenient access to public transport.

As per the Ministry of Housing and Urban Affairs (MoHUA, 2021), the urban population in India is anticipated to increase to 610 million by 2031. This will increase the demand for quality public and private transport. But only 18 out of 87 major Indian cities have an effective public transport system. This compels most city dwellers to use informal transport, which may be unsafe or environmentally unsound (NITI Aayog 2021). Public transport needs to be cheap for people with low incomes to make society equitable. According to research, public transport fares should not exceed 10% of a household budget to be affordable (OECD, 2019).Nevertheless, in most developing nations, public transport prices are still high, forcing most people to use informal means of transport (Ahmed & Mehta, 2020). Sustainable transport

policy should give high priority to accessibility for vulnerable groups, such as people with disabilities, children, and older people. One of the concerns here is the absence of universal design elements like step-free access, ramps, tactile paving, and priority seating in most cities (World Bank, 2022). Transportation emissions are one of the leading causes of city air pollution and global warming. Electric buses, non-motorized transport (cycling, walking), and enhanced public transit systems are among the sustainable transport policies that are essential in mitigating carbon emissions and traffic jams (International Energy Agency [IEA], 2021). SDG 11.2 calls for substantial public transport infrastructure investment. Developing countries must invest $1.8 trillion annually in transport infrastructure to attain sustainability targets (World Bank, 2022). TOD and integrated urban planning are being promoted as the flagship solutions to improving the efficiency of public transport (UN-Habitat, 2021). One of the most critical aspects of sustainable transport is the protection of travellers, especially women and children. Research indicates that poor street lighting, a lack of surveillance, and weak enforcement of security measures discourage people from travelling on public transport, especially at night (Chakrabarti, 2018). Measures aimed at gender-sensitive transport planning, enhanced security features, and community participation are required to overcome these issues.

Delving deeper into the environmental impact caused by the transport sector in India, a 2009 study by Ramachandra T.V. on Emissions from India's transport sector says

that transport emissions are linked to cardiovascular diseases in India and that pollution levels are primarily influenced by seasonal traffic as well as weather patterns. This study revolved around the impact of high particulate matter in urban centres.

A recent study titled "Forecasting Emissions in Indian Transport", which forecasted emissions in the Indian transport sector, claims that transportation emissions in India could rise by 40% by 2030 in a BAU (Business as usual) scenario. The study also emphasises the role of sustainable policies in reducing this number by 15-25%. (Mishra and Nirmalendu Bikash 2024) Scholars also pointed out that only 15% of transport organisations in the country conduct environmental audits.

Dr Mohan Chandran, along with Mohapatra and Subashree, in their paper 'Sustainability in Developing Nations' (2023), using an econometric model, claimed that Developing nations tend to lose 2 – 5% of GDP annually to traffic congestion. A similar study by Regmi and Madan (2024) amplifies the importance of policymakers and administrators by claiming that aligning current policies with SDGs will enhance their effectiveness by 25-30%. Rudra and Nair (2024) argue that integrated development strategies could reduce emissions by 10-20%. (Chandran, 2023).

There is also emphasis on the importance of pooled transport systems as they could cut carbon emissions by 35%. Congestion surcharges influence commuter behaviour significantly, similar to a study which explained this with sustainable practices in Kochi Water Metro (Joseph 2024) . The Kochi Water Metro reduces carbon emissions by 20%. The paper also focuses on the importance of community engagement, which was pivotal for the success of the Kochi Water Metro. (Arora 2023).

When it comes to the measurement of 'sustainability', different literature adopts various methodologies to assess how sustainable transportation systems are. Joshi, Minu and Vaidya (2017) use the Geographic Information System (GIS) based spatial analysis to highlight transportation accessibility, especially in tier 2 and 3 cities. Some also analyse congestion patterns in Indian cities and introduce a travel time index (TTI), which measures the ratio of peak hour to free-flow travel times (Chatterjee and Paul 2022) . The TomTom Traffic index supports these findings. For instance, Bengaluru has a congestion level of 71%, the highest in India. Badmi (2020) uses an emission inventory approach in cities like Bengaluru and Delhi.

On the qualitative side, study focuses on equity in the transportation system through survey-based research and finds that women, elderly individuals, and persons with disabilities face significant barriers to using public transport due to safety concerns, lack of accessibility features and overcrowding (Shah, 2018). A World Bank

document (2022) resonates this point further by highlighting the manner in which Indian public transit systems usually ignore elementary universal design elements such as ramps or tactually textured surfacing, making them inaccessible for marginalised societies.

Studies focuses on policy evaluations concerning sustainable transport governance essentially by evaluating the effectiveness of Bus Rapid Transit Systems in India, using case studies from Ahmedabad, Pune, Indore, and Dharwad (Shihora, 2018). The results showed how BRTS has improved urban mobility, operational inefficiencies and lane encroachments in the implemented areas. The paper also examines the role of a Transit-Oriented Development (TOD) to promote sustainable transport. This can be further used to address the struggle Indian cities face to integrate land-use planning with transport infrastructure, which, in the current scenario, ultimately leads to urban sprawl and increased vehicle dependency.

India has a range of studies on urban transport. However, in light of the literature review developed throughout this study, much work is absent on the sustainability measurement and its policy integration. Public transport availability, levels of congestion, emissions levels and energy efficiency have been determined in standalone studies. However, such indicators as these are rarely combined in an integrative or harmonised manner. The fact many of the policies are based on single indices, could put policymakers to develop holistically disconnected policies that

discredit the complexity of urban transport issues, while not allowing them to compare regional progress due to the lack of a single sustainability index. Going by the assumption that the world is a global village and sustainability cannot be achieved at the community level. We went by the idea of a set of indicators and targets to be measured which align with the UN SDG targets.

However, this can perhaps represent the heavy focus on India's transport policies' proximity to infrastructure expansion rather than sustainability-based policies. It is commendable to invest in metro systems, highways and electric vehicles, but the evaluation of the long-term sustainability of these investments is often complicated as there is no defined framework to determine whether these investments facilitate a more equitable or eco–friendly means of mobility. As a result, an indicator-based approach addressing all the targets of urban transport sustainability is essential to illustrate a more comprehensive picture of urban transport sustainability in India.

Research Question

How can an indicator-based approach be developed to assess the sustainability of urban transportation in India, and what policy measures are needed to ensure alignment with Sustainable Development Goal (SDG) 11?

Research Objective

To develop an indicator-based framework for assessing the sustainability of urban transportation in India and related policies and evaluating its alignment with the Sustainable Development Goal (SDG) 11.

3. Methodology

This paper mainly employs a qualitative dominant methodology focusing on policy analysis with essential quantitative technologies to assess the sustainability of public transportation in India concerning Sustainable Development Goal (SDG) 11, more specifically, SDG 11.2. Using a Bangalore case study, the paper will evaluate the sustainability of land transportation in India through indicator identification, normalisation methods, regional analysis, and policy assessment.

Table 2; Selected Indicators, Units of Measurement and their link to the SDG targets

S. No.	Theme	Indicator	Units of Measurement	Link to SDG Target
1	Environment	CO Transport emission	CO emission from transport (Tonnes/ Year)	7.3, 11.6 and 13.2
2		HC Transport emission	HC emission from transport (Tonnes/Year	7.3, 11.6 and 13.2
3		NOx Transport emission	NOx emission from transport (Tonnes/Year)	7.3, 11.6 and 13.2
4		CO2 Transport emission	CO2 emission from transport (Tonnes/Year	7.3, 11.6 and 13.2
5		PM Transport emission	PM emission from transport (Tonnes/Year)	7.3, 11.6 and 13.2
6	social	Traffic deaths	Total number of traffic deaths over a year	3.6 and 11.2
7		Vehicle ownership per capita	Total number of registered motorised vehicles per capita (Vehicles/Capita)	11.2
8		Drunk driving cases	No. of drunk driving cases registered per year	11.2
9		Unsafe driving cases	No. of unsafe driving cases registered (Signal jump, without license, etc.) per year	11.2
10		Vehicle Kilometre Travelled	Total VKT (million Km/day)	11.2
11	Economic	Population Density	Persons per square km	11.2
12		Per capita trip rate	Average number of trips per person (Km)	11.2
13		Public transit network (Metro)	Total public transit network coverage (Metro)	11.2
14		Public transit ridership (Bus)	Public transit daily ridership per day (Bus)	11.2
15		Public transit ridership (Metro)	Public transit daily ridership per day (Metro)	11.2

Indicator Identification and Selection (Aligning with SDG 11.2)

To assess the sustainability of transportation systems through a measurable indicator-based approach, it is crucial to select suitable indicators which are measurable and are listed by the United Nations. These indicators are based on SDG 11.2, which aims to provide safe, accessible, affordable and sustainable transport systems for all. United Nations SDG frameworks, national transport policies, and academic literature thus guide the selection. The indicators have been broken down regarding their Environmental, social and economic impact. This selection is based on the "SMART" criteria (Specific, Measurable, Attainable, Relevant and Timely)

Essential quantitative models are used in this study to measure the progress made in the transportation scenario concerning Sustainable Development goals. Global averages and U.N defined targets are selected for the same, which are integrated into the index formation, which is done through a modified min max methodology proposed by the Indian Institute of Science (Sustainable Transportation Lab). Our paper has given equal weightage to Environment, Social and Economic indicators for simplicity. However, regional variations should be given importance, and weights should be assigned based on the region under study. Going solely by theory, these indicators can further be aggregated to get the STI (Sustainable Transportation Index).

Normalization of Indicators and formulation of the Index

This process begins with normalising the selected indicators with a modified min-max method, allowing us to have a standardized range where all indicators are expressed between 0 and 1. Indicators which positively affect sustainability like population density (IISc, 2023)

$$N = \frac{I - \min(I)}{tar(I) - \min(I)}$$

In the case of indicators having a negative impact on sustainability, like CO2 emissions (IISc, 2023)

$$N = \left(1 - \frac{I - tar(I)}{\max(I) - tar(I)}\right)$$

These indicators are further aggregated, assigning equal weights to form three sub-indices, which correspond to the three already listed perspectives; economics, social and economic. Similarly, the STI is calculated is by aggregating these three indicators.

$$CSTI = \frac{\gamma 1 IEnv + \gamma 2 ISoc + \gamma 3 IEcon}{\gamma 1 + \gamma 2 + \gamma 3}$$

where γ is the equal weight assigned to each of the indicators.

Following the calculation of the Sustainable Transport Index (STI), policy-oriented analysis has been conducted to determine the role of governance in shaping sustainable mobility outcomes. This involves examining the trends observed in CO_2

emissions, accident rates, and per capita vehicle ownership and correlating them with policy interventions at the national, state, and city levels. Such a comparative assessment of transport sustainability by analysis of the STI scores in the different regions and identification of policy-induced discrepancies is to determine their alignment with Sustainable Development Goal (SDG) 11.2. The approach involves mapping policy changes onto observed trends in the key transport indicators.

Ordinary Least Squares (OLS) regression is also used to quantify the correlation between rising private car ownership and rising CO_2 emissions, and thereby quantify the level of policy success of public transportation systems. In addition, time-series analysis of accident rates is beneficial for the evaluation of the long-term success of interventions aiming to improve road safety. Coupling quantitative results with policy analysis, the method provides a framework for establishing if transportation-related policies in the country are favourable in terms of sustainability. There is a case study of the Bengaluru metropolitan region as an effort to measure the effectiveness of sustainable mobility policies of transport in the city. Bangalore has adopted a Transit Oriented Development (TOD) strategy through integrating land use planning as well as investments into new public transport. Through the expansion of the Bangalore Metro (Namma Metro), the study evaluates how the Bangalore sustainable transport policy may be achieved and what two future mobility scenarios may do to the sustainability of Bangalore.

Projected future emissions level, congestion, and public transport ridership for Business-as-Usual (BAU) scenario, such as calculated using linear regression models, to deploy the same unaltered scenario of current mobility trends without any additional interventions. The projected amount of enhanced public transport accessibility, VKT reduction, and emissions savings is then compared to the Sustainable Mobility Scenario with the provision of terms of Metro Phases 2, 2A and 2B as projected by the Govt of Karnataka. Since Bangalore's Comprehensive Mobility Plan is aimed at providing safe, accessible and sustainable transport for everyone, the effects of its implementation in terms of investment in metro rail, bus rapid transit and pedestrian facilities are being evaluated to see whether their contribution to the fulfilment of SDG 11.2 objectives is sufficient or not. The adopted research approach for this present study is very much aligned with the research objective of this study, i.e. the assessment of the Indian transport scenario of SDG 11.2, which talks about ensuring accessible, safe, and sustainable transport systems. Quantitative methods, including the Sustainable Transportation Index (STI), regression analysis, travel demand modelling and qualitative analysis based on a policy focus, are employed in an integral approach to the assessment of transport sustainability.

Aggregation and normalisation of a group of key indicators—CO_2 emissions, accident rate, and per capita car ownership—constitutes an analytical framework for transport sustainability measurement at the country and inter-country level. In

addition, OLS analysis places the quantitative estimation of the effect of private car expansion on emissions in a policy implication context using a quantitative basis. The Bangalore case study further illustrates this research by analysing sustainable urban mobility measures in the context of a fast-growing city. A comparison between the BAU scenario and the Sustainable Mobility Scenario in the study illustrates the long-term benefits of investment in TOD, metro expansion, and non-motorized transport infrastructure. This can be implemented in other urban cities of the country to achieve the ambitious zero emission goals and adhere to the global sustainability frameworks.

4. Analysis, results and discussions

The section evaluates the perspectives of India's transport sector through the lens of Sustainable Development Goal (SDG) 11.2), which aims to ensure safe, affordable, accessible, and sustainable transport for all. This section proceeds to give a qualitative-dominant analysis with essential quantitative analysis and evaluation of significant indicators such as per capita vehicle ownership, CO_2 emissions, and road accident rates in the light of their significance in assessing the degree to which India's transport system aligns with sustainability objectives. The study results would provide insights into historical trends, present-day challenges, and future projections to eventually inform policy recommendations towards improving the sustainability of public transport.

The analysis starts with a qualitative examination of the key transport indicators based on historical data (2000-2024) to gain insights into the path of India's transport system. The indicators are normalised by min-max normalisation so they can be compared well across the variables. Following this structured process Indian transport sustainability is then assessed to three pillars, the environmental (I_env), social (I_soc) and economic (I_econ). The three indicators are combined into the Sustainable Transportation Index (STI) from here, which sums all three indicators to arrive at an overall measure of transport sustainability.

A regional Transit-oriented Development (TOD) review is first conducted, and then, different transportation trends in urban centres are assessed. This section analyses the variables that distinguish high-density urban areas from small towns and whether the public transport system addresses the conflicting needs of the people today. The forecasting models are used to forecast travel demands just before 2031 in two scenarios: a Business as Usual (BAU) and a Sustainable Transport (ST). Here, we highlight the impact of a select set of policy interventions on the sustainability outcomes related to improving public transport networks, electric mobility penetration, and road safety. Secondly, a case study of the Bengaluru metropolitan region gives a detailed account of a city that has suffered rapid urbanisation and its ensuing transport-related problems. This study assesses the impacts of implementing

metro development, bus fleet electrification, and decongestion measures to ascertain if Bangalore's transport policies are working towards SDG 11.2 targets.

Last, the section ends with a turn of the critical policy wheel, contrasting India's transportation policies with global best practices. By integrating empirical evidence and qualitative policy analysis, this section will identify strengths and gaps and propose potential areas for future development in India's transport sector. The section's findings will guide concrete recommendations towards developing an environmentally sustainable, socially inclusive, and efficient public transport system in India.

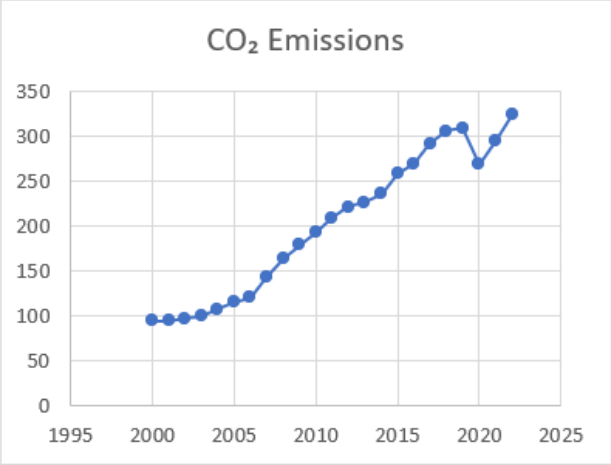
Indicator-based Assessment of Sustainability of Transportation in India

As mentioned earlier, 15 indicators have been listed to ensure sustainability in the Environmental, Economic and Social spheres.

For the environmental factor, a modified min-max normalisation technique was applied to historical CO2 emissions data as this would help quantify the progress towards meeting global ecological targets. Instead of the utopian net zero emissions, A sustainability goal of 100 Mt C02 was selected based on literature review and the normalisation formula was used to generate an index which range from 1 (ideal sustainability) to 0 (worst sustainability). In this case, the normalisation indicates a constant decline in sustainability over time; over the years, the index has

progressively decreased, and the minimum value will be achieved in 2022. This raises questions about the efficiency of environmental-related policies in the country.

Figure 4; Co2 emissions of India from 2000 to 2022 (Mt CO2)



Source: Ministry of Road Transport and Highways, India

Table 3; Normalization of CO2 emissions

Year	CO_2 Emissions	Normalized Index
2000	95.089	1.0219
2005	115.403	0.9312
2010	192.918	0.5847
2015	257.747	0.295
2020	268.679	0.2462
2022	323.762	0

Source: Author's calculation

India's transport sector also shows a wide variation in emissions by mode. Looking at per capita emissions; Road freight transport (160 gm/tkm) produces much more CO_2 than rail (29 gm/tkm) and shipping (31 gm/tkm), reflecting logistics inefficiencies and excessive use of road transport which can turn out to be unsustainable in the long run. Similarly, car-borne passenger transport (175 gm/tkm) and air transport (229 gm/tkm) is far more carbon-hungry than rail transport (75 gm/tkm), pointing towards the sustainability benefit of increasing the efficiency of rail transport in India for both freight and passengers. India's transport emissions are somewhat unfavourable to global norms, particularly for road and aviation travel, and in doing so, they conflict with the ambitions of SDG 11.2 from the environmental perspective.

Table 4; Co2 emissions per capita

Mode	Category	Transport (gm/tkm)
Road	Freight	160
Rail	Freight	29
Shipping	Freight	31
Road	Passenger	175
Rail	Passenger	75
Airways	Passenger	229

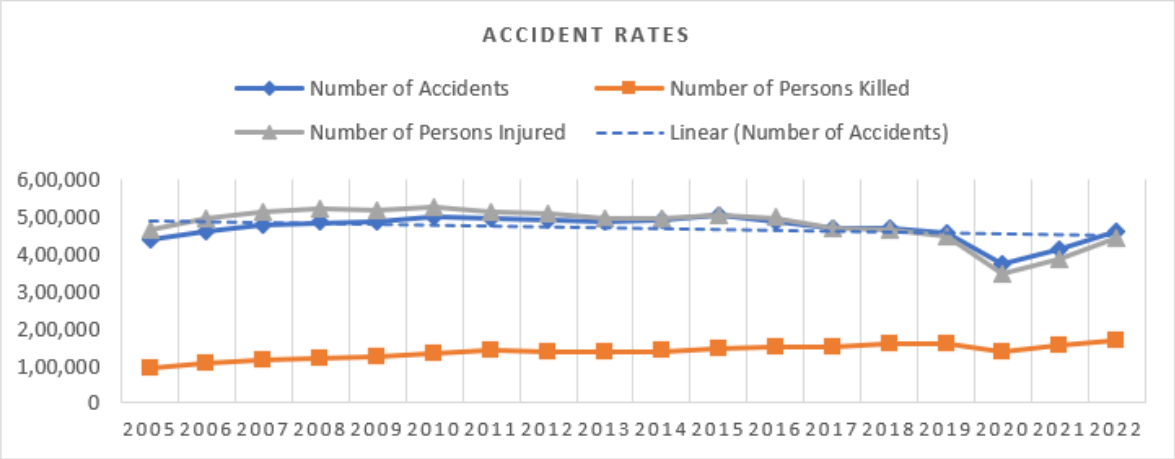
Source: Ministry of Road Transport and Highways

Policy impact has come in twofold—whereas investment in motorways and incentives for private vehicle purchases have resulted in higher road emissions, programs such as railway electrification, metro development, and the development of inland waterways seek to limit emissions. These nonetheless have not yet yielded substantial savings as the proportion of rail freight is not carrying a suboptimal proportion of freight transport. To realize the world's best practices and achieve India's 2070 Net Zero commitment, it has to be policed very strongly as to favour inter modal modes of transport complementing each other, provide public transport in urban areas to an extent and become sterner on norms of emissions on vehicles and airplanes. But India's per capita carbon dioxide emissions are lower than the world average. The rising CO2 emissions since 2000 is an indication that policies regarding the evaluation and the control of environmental destruction have to be changed.

Moreover, min-max normalization techniques are used to compare road accidents and death rates in India using the adjusted min-max normalisation technique in order to quantify the amount of disparity in terms of the minimum road accidents and minimum fatalities of various years in achieving the target of least road accidents and least fatalities. The higher the index value, the closer to sustainability we are, and the lower the index value, the worse the scenario is deteriorating. From the stats, there seems to be an unceasing rise in road accidents and deaths from 2005 to 2015, with 2015 being our highest number of accidents and one of our highest fatalities.

This corresponds with high urbanisation rates, rising car ownership, and infrastructural limitations in coping with road safety. The accident index was at its lowest (0.0000) in 2015, showing a surge in accidents and road fatalities. However, in 2020, although there was a high increase in the accident index value, thanks to the lockdowns due to COVID-19, accidents sharply fell (1.2630). However, the fatalities index (0.3835) was still low, indicating fewer accidents, but the severity of deaths was higher from the dangerous driving on deserted roads. Further down, the road accident index dropped again to 0.4203 by 2022, fatalities were at their worst point (index = 0.0000) and have an imperative for renewed road safety measures. In order to reduce accident-related fatalities, India has made several efforts to improve road safety. The Motor Vehicles (Amendment) Act 2019 enhanced penalties for traffic offences, set up better safety norms and improved accountability of road users. The National Road Safety Policy also emphasises on increased awareness campaigns, improved emergency responses and improved road engineering standards. With these events, there still has been a continued increase in fatalities (2022 was the worst yet), suggesting that improvement is still needed in implementation.

Figure 5; Accident rates in India from 2005 - 2022



Source: Ministry of Road Transport and Highways

SDG 11.2 focuses on ensuring access to safe, accessible, and sustainable transport systems for vulnerable groups such as pedestrians, cyclists, and public transport passengers. India's road safety performance, as captured in the negative indices from 2005-2022, indicates that prevailing transport systems continue to be unsustainable and unsafe and fail to achieve the fundamental targets of SDG 11.2.

Table 5; Accident Index and fatalities Index

Year	Number of Accidents	Number of Persons Killed	Accidents Index	Fatalities Index
2005	439,255	94,968	0.6289	0.9367
2010	499,628	134,513	0.0580	0.4329
2015	505,770	146,555	0.0000	0.2794
2020	372,181	138,383	1.2630	0.3835
2022	461,312	168,491	0.4203	0.0000

A sustainable transportation framework must prioritise public over private transport. The increasing accident trends correlate with the rise in motor vehicle ownership, reinforcing the need for more significant investments in high-quality public transport networks to discourage reliance on personal vehicles. Additionally, road safety policies should align with Vision Zero principles, which advocate for eliminating road fatalities through better infrastructure, stricter regulations, and behavioural change programs.

As reviewed by the Sustainable Development Lab of the Indian Institute of Science, the Sustainable Transport Index (STI) is designed to evaluate the sustainability of India's transport system over time by incorporating environmental, social and economic factors. As mentioned earlier in Section 3, we have used the modified min-max normalisation technique, and we have derived interpretations about the transport scenario in India with SDG 11.2.

The values range between 0 and 1; the higher the index, the higher the sustainability in the transport sector.

Table 6; Calculation of the Sustainable Transport Index (STI)

Year	CO_2 Emissions (MT)	CO_2 Index	Accidents	Accidents Index	Vehicles per Capita	Ownership Index	Population Density	Density Index
2000	95.089	**1**	4,39,255	**0.92**	46	**1**	322.35	**1**
2005	115.403	**0.825**	4,60,920	**0.875**	71	**0.797**	351.25	**0.867**
2010	192.918	**0.312**	4,99,628	**0.8**	103	**0.503**	377.4	**0.724**
2015	257.747	**0**	5,05,770	**0.786**	158	**0.089**	402.42	**0.569**
2020	268.679	**0**	3,72,181	**1**	233	**0**	424.79	**0.433**
2022	323.762	**0**	4,61,312	**0.894**	248	**0**	431.11	**0.4**

Aggregation is done by assigning equal weights (0.25)

Table 7; Sustainable Transport Index

Year	CO_2 Index	Accidents Index	Ownership Index	Density Index	STI
2000	1	0.92	1	1	0.98
2005	0.825	0.875	0.797	0.867	0.841
2010	0.312	0.8	0.503	0.724	0.585
2015	0	0.786	0.089	0.569	0.361
2020	0	1	0	0.433	0.358
2022	0	0.894	0	0.4	0.324

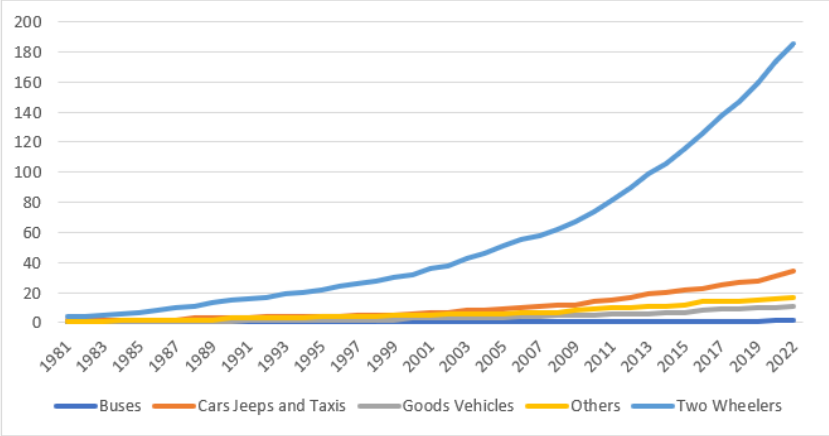
Source: Author's calculations

The Sustainable Transport Index (STI) has captured the alarming deterioration in transport sustainability in India over the years, which is due to the problems of SDG 11.2. It was highest (0.980) in 2000, when transport sustainability was at its best (according to available data). It was so because there were low CO_2 emissions, fewer road accidents, fewer vehicles, and less urban congestion. However, over the years, there has been a steady decline; in 2005, the score fell slightly to 0.841, presumably due to rising emissions and more vehicles. In 2010, the situation worsened further, with sustainability falling to 0.585 as CO_2 emissions and vehicle ownership went up exponentially, resulting in more congestion and urbanization problems. This trend was followed in 2015, when the STI fell to 0.361, capturing serious deterioration in sustainability due to high reliance on private cars, peak CO_2 emissions, and high accident rates. Even in 2020, although accidents first fell due to COVID-19 lockdowns, sustainability was low at 0.358 because vehicle ownership per capita had already become unsustainable. By 2022, the STI fell to its lowest (0.324), the worst period for transport sustainability in the dataset. The combination of high car ownership, rising road accidents, rising emissions, and worsening urban congestion has severely impaired sustainable mobility, making it difficult to achieve SDG 11.2.To address these challenges in the current policies, a package of policy recommendations needs to be put in place. CO_2 emission reductions are imperative, which can be done by electrifying transport (EVs and metro expansion), congestion charging, and increasing fuel efficiency standards. Accident rates must be regulated by tightening traffic enforcement using AI-based monitoring, encouraging safer

pedestrian infrastructure, and increasing bicycle lanes. Reducing high vehicle ownership and congestion entails encouraging shared mobility solutions, more investment in metro and rapid bus transit, and improved last-mile connectivity. Coping with urbanisation and population density calls for transit-oriented development (TOD), ensuring high-density residential development close to metro and bus corridors, and decentralising city growth by investing in smart satellite towns to curb congestion in core cities.

One of the leading causes of rising CO2 emissions and accident rates is India's exponential rise in vehicle ownership per capita, from just 8 per 1000 people in 1981 to 248 per 1000 in 2022. Even though such a trend can mean greater economic welfare as private vehicles have become more affordable over the years, the trend also has had a huge impact on the country's transport sustainability.

Figure 6; Rising vehicle ownership per capita in India



The multiple regression between private vehicle ownership and CO_2 emissions shows a Multiple R of 0.931, which is a high positive correlation between the two variables. The R^2 of 0.866 indicates that 86.6% of the variation in CO_2 emissions is explained by the rise in private car ownership, which is a high impact. The Adjusted R^2 value of 0.858 assures us that explanatory power is high even with control for likely model complexity.

Table 8; Results of OLS estimation between private vehicle ownership and Co2 emissions.

Regression Statistics	Column1
Multiple R	0.930615694
R Square	0.866045569
Adjusted R Square	0.857673417
Standard Error	19.75758795
Observations	18

Source: Author's calculations

The close correlation between private car ownership and CO_2 emissions necessitates action on green transport. As 86.6% of CO_2 reduction comes from other private cars, policymakers have to address cutting the use of such cars by concentrating and investing in public transport systems such as metros and bus rapid transit (BRT). Imposing levies on driving in congested areas is a step that has to be undertaken to cut emissions. In addition, more stringent fuel efficiency standards such as the new BS6 norms and further taxation on fossil fuel vehicles can deter people from using cars so extensively, pushing them towards cleaner alternatives. Changes in city planning must also be in line with targets for sustainable transport.

Promoting transit-oriented development (TOD)—housing, stores, and establishments along efficient public transport—can reduce car dependency and emissions. Promoting non-motorized transport (NMT) infrastructure, i.e., bike lanes and pedestrian streets, can promote people to travel in less polluting ways. If we do not act now, more people will be private-car owners, deteriorating air quality, traffic

congestion, and making it harder to achieve SDG 11.2. The goal is to provide safe, affordable, accessible, and sustainable transport for everyone.

Case study: Bengaluru Urban Region

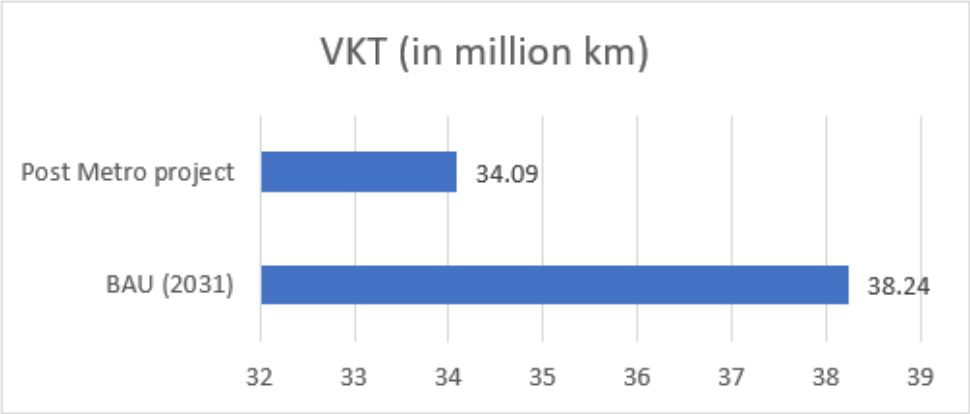
Bengaluru is one of the first cities in India to develop a comprehensive mobility plan focusing on sustainability and accessibility of public transport. Such an approach adheres to the goals of SDG 11, mainly target 11.2. This strategic approach aims to build a multi-modal transport system focusing on accessibility and, more particularly, less negative externalities.

The TomTom index lists Bengaluru 3rd in the world with respect to travel time, with an average travel time of 34 min 10 seconds per 10km.

Using a linear regression model, the Business as Usual (BAU) scenario for Bengaluru has been estimated up to 2031. The comprehensive mobility plan also includes a metro scenario, where the proposed metro rail project: Phase 2, Phase 2a and Phase 2b. This particular transit-oriented approach emphasises a high share of public transport usage. Public transportation systems must attain operational efficiency to maximise output and improve commuter convenience while building infrastructure and capacity is crucial.

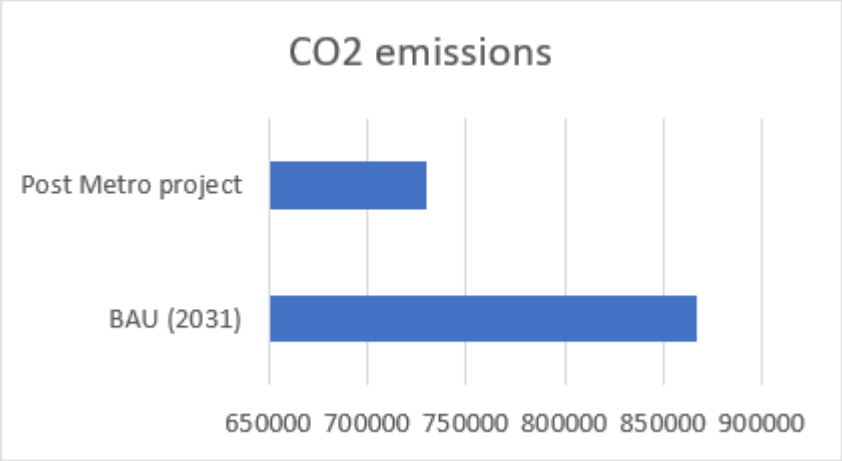
Comparing the BAU scenario and the projected statistics post the completion of metro phases and the implementation of the transit-oriented approach. Vehicle kilometres travelled by 2031 is expected to decline by around 10.85% from 38.24 million km (BAU) to 34.09 million km. We can interpret this reduction as reducing congestion and lower dependence on private vehicle use for daily trips.

Figure 7; Comparison of VKT of the BAU and Post Metro Completion scenario



From the environmental perspective, CO2 emissions are expected to drop by 15.79%. The report majorly emphasizes the role public transportation has in reducing a nation's carbon footprint from the city level, ultimately supporting the nation's goal to achieve a sustainable zero-emission goal. The reduced Co2 emission is also attributed to higher ridership in public transportation. $PM_{2.5}$ emissions are also expected to fall by about 19% from 102 tonnes/ year in the BAU scenario to 83 tonnes/year.

Figure 8; Comparison of Co2 emissions of the BAU and Post Metro Completion scenario



In the transit-oriented approach taken by the Karnataka government for Bengaluru, the prime focus lies in increasing ridership in public transportation. With the construction of phases 2, 2a and 2b of Namma Metro, ridership is expected to rise by almost 90% from 18.43 lakh passengers daily to 35 lakh daily passengers. This aligns with the overall target of SDG 11.2 by improving accessibility and commuter preference for a sustainable mobility option.

Now going back to the STI index, with the current projections, the STI is expected to increase by around 9.46% from around 0.647 to around 0.708.

The Bengaluru Metropolitan Transport Corporation (BMTC) has a significant role to play in this mission. With a fleet of 5642 buses, BMTC has seen its average ridership increase from around 27 lakhs to 37.3 lakhs following the implementation of the recent Shakti scheme offering free bus travel for women. The KIA airport feeder buses have also reduced dependence on private vehicles as far as airport goers are concerned. The synergy between BMTC and Namma Metro remains crucial to achieving the larger goal.

Table 9; BMTC statistics

Parameter	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19 (as on Aug-18-Prov.)
Depots	39	39	40	40	43	44	45
Vehicles Held	6431	6775	6522	6401	6161	6677	6634
Effective Km. Per day (Lakh)	12.71	13.14	12.9	12.21	11.52	11.42	11.38
Total Service km (Lakh km)	4638.38	4795.90	4708.56	4469.82	4205.20	4164.53	-
Veh. Utilisation (Km)	221.1	218.2	214.5	208.5	206.5	203.8	202
Passengers carried per day (Lakh)	48.46	50.25	51.30	50.74	45.34	44.37	-
Passenger load factor (%)	68.5	67.2	75.8	74.2	68.8	66.8	-

Bengaluru's transport model is something that other fast-developing cities in India plagued by traffic issues can learn from. With the adoption of a smart and efficient

transport plan, the city has gone a long way in simplifying travel and making it sustainable. One of the strongest aspects of this model is the manner in which public transport coordinates with each other, with the metro and bus systems working well in sync with each other. This enhances connectivity, saves time, and facilitates people to move around easily, making it efficient and affordable. Another major aspect of Bengaluru's transport plan is its all-encompassing policies.

Initiatives such as the Shakti scheme, under which women travel free on buses, demonstrate the power of well-designed inclusive policies. Such policies promote the use of public transport, lower personal transport usage, and make effective means of travel accessible to everybody. One example of effective policy-making is the making of public transport more affordable and accessible for more people in Bengaluru. The other central pillar of Bengaluru's urban transport system is technology. ITS and real time information has dramatically improved the feeling people now have about the system and makes us quite happy with it. The main thing that they provide is the ability to route planning, control traffic, and even monitor what happens in total, all in real-time, to make transport easier and more reliable. Doing so will enable Indian cities to devise good and sustainable urban transport systems for many environmental and infrastructure purposes. Relieving traffic congestion, reducing pollution and improving the quality of life in cities could be accomplished by way of public transportation, inclusive policies and smart technology.

5. Conclusion

This study attempted to quantify India's public transportation sustainability against Sustainable Development Goal (SDG) 11.2, focusing on safe, accessible, and affordable transport for all. Qualitative-dominant research complemented with requisite quantitative approaches are used, which mainly involved relevant indicators such as CO_2 emissions, accident rates, and vehicle ownership per capita quantification through processes of normalisation and aggregation to estimate the Sustainable Transportation Index (STI). The work shows that despite foreign investments in Indian public transport, the growth of private vehicle ownership remains a major obstacle to sustainability. The powerful impact of private vehicle growth on emissions was confirmed by the Ordinary Least Squares (OLS) estimation, and as such, the importance of policies that encourage public transit, walking, and biking, which also reduces emissions, was further highlighted.

A line by line analysis of the TOD approach of the Bengaluru metropolitan region was also conducted in a case study of which city offers a good case for providing mobile to towns. The report also revealed how much further investments in public transport infrastructure could be used to compare with the BAU scenario (based on linear regression models) against the Sustainable Mobility Scenario (based on metro phases 2, 2A and 2B extensions). Multi-modal integration, when well implemented

and supported by turned-on policies, will significantly reduce VKT, emissions and accessibility.

Part of India's shift towards sustainable urban transport is manifested through its investment in metro extensions, bus rapid transit (BRT) systems and non-motorized transport (NMT) infrastructure. These problems, however, tend to remain in terms of last mile connectivity issues, finances and inefficiencies of operating public transportation. Therefore, policies have to target increasing the accessibility and affordability of public transport in a manner that can be made available to marginalised sections to take advantage of transportation benefits. Analysis of transport per capita and Co2 emissions suggests that transport by road is still dominant is one of the major causes of Indian urban air pollution. Investments in metro and electric bus plans, a stronger incentive for the electrification of buses as well as congestion charges and stricter emission standards are required. Tax policies for vehicles must thus be framed to discourage car ownership to ultimately promote the usage of low emission options.

The study of accident rates determined a pattern of increasing fatalities despite efforts to enhance road safety. Policy interventions such as stronger enforcement of traffic laws, improved road design, and more pedestrian infrastructure must become priorities. Adding road safety education to urban planning programs can lead to more sustainable long-term benefits. The Bangalore case study showed the prime role of

land-use planning towards transportation sustainability. TOD planning in densifying urban development along metro and bus corridors can lead to reduced congestion as well as enhanced mobility efficiency. The same planning must be replicated to other high-density Indian cities in a manner that urban growth is accompanied by public transport connectivity. The Bangalore case study showed the prime role of land-use planning towards transportation sustainability. TOD planning in densifying urban development along metro and bus corridors can lead to reduced congestion and enhanced mobility efficiency. The same planning must be replicated to other high-density Indian cities so that urban growth is accompanied by public transport connectivity.

The first step towards India's efforts to achieve the zero emission goal is to strengthen the public transport networks in the country by creating a comprehensive mobility plan regarding investments in metro and bus rapid transit systems (BRT) with first and last mile connectivity. Applying congestion pricing and incentivizing private vehicles can deter over reliance on private transport. From a social perspective, it is necessary to pass more stringent road safety laws and make punishments for traffic offenses more stringent. Like the Bengaluru approach, India should encourage a transit oriented development approach that would cluster high density areas near transit canters.

Whereas the current research provides a complete analysis of the transport sustainability in India, the future research would explore other areas such as transport accessibility social justice, economic efficiency of emerging mobility solutions, and climate resilience possibilities for transport systems. Regional case studies beyond Bangalore can also provide more general insights into different transport problems faced by different Indian cities. This study underscores the imperative policy-interventional needs to evolve sustainable mobility in India. It must have an integrative, balanced strategy that includes the evolution of public transport, stringent regulation of emissions, road safety, and transit-oriented developments for the achievement of SDG 11.2. As India continues to progress urbanization at a rapid rate, evolving a robust, inclusive transport system will be key to evolving future sustainable cities.

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Understanding the Perception of Climate Change among College Students in Pune, Maharashtra

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Abstract

Climate change is a threat to global sustainability. Having a perception about climate change is so important to address this challenge. The City of Pune is home to a large urban population with a significant size of youth. This study investigates the perception of climate change among college students in Pune City. Primary data will be collected with the help of an online survey. This research aims to understand students' ideas and observations about what is climate change, its causes, how it impacts the globe, and their willingness to adopt sustainable practices. The research also explores the role of educational institutions and social media in shaping these perceptions. The data collected will be analyzed using various statistical tools like

the chi-square test to examine relations between awareness levels and behavior intentions, the impact of social media on awareness, gender, and perception of climate change, and role of educational background on awareness. The findings will help identify gaps in climate change education and also suggest strategies for improving eco-conscious behavior among students. This study contributes to SDG 13 (Climate action), highlighting the importance of ESG in educational settings.

Keywords - Climate change, Perception, College students, Sustainability

1. Introduction

"We are the first generation to feel the impact of climate change and the last generation who can do something about it."

— Barack Obama, former U.S. President.

The climate has changed in the past, is changing in the present, and will change in the future - It is a reality. It is the long-term shifts in temperature, precipitation patterns, wind patterns and other aspects of Earth's climate system. Science acknowledges human activities as the primary cause of climate change, yet the perception about climate change is varied, which influences their action towards achieving sustainability.

India is often referred to as "Youngistan[1]" (a term denoting the country's youthful demographic, with over 50% of its population under 25) due to the large proportion of its population being young people, with over 50% of the population under the age of 25. These young individuals, especially college students, represent the future of the nation and hold the key to addressing many of the pressing issues we face today, including climate change and environmental sustainability. Pune, a prominent metropolitan city in India, is home to a large number of educational institutions and attracts students from diverse regions of the country as well as internationally. However, Pune also grapples with significant environmental challenges, particularly in the realm of air pollution and the degradation of natural resources.

The city's pollution levels have been steadily increasing, primarily due to the heavy reliance on two-wheelers, increased vehicle emissions, and industrial activities. This has contributed to deteriorating air quality, which affects the health and quality of life of residents, especially the younger population. College students, being a major part of Pune's population, are in a unique position to contribute to and advocate for solutions to these environmental issues. Their perceptions of climate change, its impacts, and the need for sustainable practices will play a crucial role in shaping future policies and lifestyle choices.

[1] Youngistan is a colloquial term popularized in India to emphasize its youthful population and their potential in shaping the country's future policies and development

A diverse group of students from different states and even countries call Pune home during their academic years. This cultural and geographical diversity offers an opportunity to understand varying attitudes and perceptions towards climate change and sustainability. It is essential to explore these perceptions, as fostering a positive and proactive attitude toward climate change is critical to developing the collective willingness to adopt sustainable practices.

Sustainable practices, when implemented by the youth, have the potential to significantly mitigate the effects of climate change and slow down global warming. By understanding how college students perceive climate change, we can tailor education and policies to encourage responsible actions such as reducing waste, promoting renewable energy, conserving water, and advocating for green technologies. These practices, if widely adopted, will contribute not only to improving air quality in Pune but also to advancing India's commitment to global climate goals. Therefore, understanding and shaping the perception of climate change among Pune's college students is a crucial step toward building a more sustainable and environmentally responsible future.

A thorough review of the existing literature reveals several critical gaps in our understanding of climate change perceptions, particularly in urban areas like Pune. Despite Pune's rapid urbanization and significant environmental challenges, such as pollution and resource depletion, there remains a lack of comprehensive research on

how college students in the city perceive climate change. This is surprising given the growing recognition of the environmental issues faced by urban centers.

In addition to this gap in perception studies, much of the literature also points to the "education-action gap"—a phenomenon where there is a disconnect between the knowledge people have about climate change and their subsequent actions to address it. Research suggests that although many individuals, including students, are aware of the climate crisis, this awareness often does not translate into substantial behavioral change or environmental activism. This gap highlights the need for not only more targeted educational efforts but also for strategies that effectively bridge the divide between awareness and action.

Furthermore, the literature underscores the importance of perceptions in influencing environmental behavior. How individuals perceive climate change—whether they view it as an urgent and existential threat or a distant concern—can significantly shape their actions. In particular, college students are seen as a crucial demographic in this regard. As the future leaders, policymakers, and influencers of society, their perspectives and actions can play a pivotal role in driving climate action on a larger scale. With this in mind, understanding the factors that influence college students' perceptions of climate change is essential for creating effective educational and policy interventions aimed at fostering sustainable behavior and promoting climate activism among the younger generation.

Scope of the study - to provide valuable insights into college students' perceptions of climate change, which will be beneficial to colleges, institutions, parents, teachers, government bodies, and researchers. Understanding these perceptions will help identify the factors influencing students' views on climate change and highlight areas where awareness or engagement may be lacking. By examining the reasons behind the reluctance to adopt sustainable practices, the study aims to identify actionable solutions. This will enable stakeholders to address gaps, promote behavioral change, and implement strategies that can contribute to effective climate action and sustainable practices. The study will contribute to academia, policy, industry, or society.

2. Literature Review

This literature review looks into how college students in Pune perceive climate change, especially considering the city's fast urban growth and environmental challenges. It dives into existing research on students' awareness of climate issues, what influences their views, and how these perceptions could affect their actions. The review also points out some gaps in current studies and stresses the importance of closing the education-action gap to encourage more sustainable behaviors and climate action in the future.

Sr. No.	Author(s)	Findings
1	Leiserowitz et al. (2021)	Response of individuals and societies to environmental challenges is influenced by perception on climate change.
2	Moser & Dilling (2011)	Identified Youth, college going students in particular, as the key agents in climate action as they are the future leaders.
3	Capstick et al. (2015)	Identified education, media exposure and direct climate experience as the factors affecting perception.
4	Mead et al. (2020)	College students are aware about climate change but their understanding with regard to causes and solutions seems to differ.
5	UNICEF (2022)	Global survey showed that around 75% of the young population validates climate change as a threat but the visible lack of power to take action is a major problem.
6	Singh & Gupta	Highlighted disparities in access to environment education by revealing that urban students are more aware of climate change compared to rural students.
7	Velasquez & Quenette (2020)	Highlights the dominant role of social media in shaping environmental consciousness in young people.

8	Gupta & Jha (2023)	Reveals that those students interested in climate related content on social media are more likely to adopt sustainable practices.
9	McCright & Xiao (2014)	Highlights that, compared to men, women generally express greater concern about climate change.
10	Patel et al. (2022)	Found that students of female gender are more inclined to support environmental initiatives and practice sustainable behaviour.
11	Kollmuss & Agyeman (2019)	Students from science stream shows more grasp of climate science than the students from non-science background.
12	Mukherjee & Ghosh (2022)	Highlighted the knowledge action gap among students, while they are aware of climate change, very less percentage are practicing sustainable behaviours.
13	Thapar et al. (2019)	Studies the perceptions, attitude and practices regarding climate change among college students in coastal south India which highlighted varying levels of awareness and the effect of socio-cultural factors on their behaviours.
14	Pawar et al. (2019)	Conducted a study on air pollution and the associated health risks in traffic police in Pune, and highlighted the gap in exposure and lack of awareness about pollution related health risks.

Table 1.1 Literature review

Despite many studies on perception of climate change among students across the globe or other regions, there is a lack of focus on the City of Pune and its college students. Pune is known as the educational hub with a large number of institutions, having students from different states, different cultures, rural as well as urban areas, and even from other nations. However, understanding the perception of climate change among college students in Pune city remains under-studied. Also, having a perception about climate change is important, especially in a city like Pune, which is experiencing significant urbanization and related environmental challenges like air and water pollution, water scarcity and waste management issues, because having a perception is important to inculcate willingness to do sustainable practices.

Objectives

The objectives of this research are

1. To assess college students' perception of climate change in Pune, including their beliefs about its causes, severity, and impacts.
2. To analyze how educational institutions, social media, and peer discussions shape students' perceptions of climate change.
3. To identify differences in climate change perception based on demographics such as gender, academic background, and field of study
4. To explore the relationship between students' perception of climate change and their willingness to adopt sustainable behaviors.

Hypothesis

Ho1 - College students in Pune do not have a varied perception of climate change, with notable differences in their views on its causes, severity, and impact.

Ha1 - College students in Pune have a varied perception of climate change, with notable differences in their views on its causes, severity, and impact.

Ho2 - Exposure to educational institutions, social media, and peer discussions does not significantly influence students' perception of climate change.

Ha2 - Exposure to educational institutions, social media, and peer discussions significantly influences students' perception of climate change.

Ho3 - There is no positive correlation between students' perception of climate change and their willingness to adopt sustainable behaviors.

Ha3 - There is a positive correlation between students' perception of climate change and their willingness to adopt sustainable behaviors.

3. Research Methodology

The primary data was collected using a stratified random sampling method. The collected data was then analyzed with the help of various statistical tools and computer applications like the Chi-square test, Cramer's V or Spearman's Rank correlation, and logistic regression to analyze the perception of climate change among college students in Pune city. It will also examine other variables or factors affecting the perception of climate change. Different research papers, articles, and government reports have been analyzed to support the hypothesis. The next chapter of the Review of Literature includes the studies previously done on the various elements of perception of climate change, the education-action gap, and factors associated with willingness to adopt sustainable practices.

4. Data Analysis & Discussion

For the analysis and findings of the data, data of 144 students from Pune city from different colleges having different streams of degrees, studying in different years of their education. Different statistical techniques like Chi-square test, Cramer's V, logistic regression was used to analyze the data.

A] Hypothesis 1

H0 - College students in Pune do not have a varied perception of climate change, with notable differences in their views on its causes, severity and impact.

H1 - College students in Pune have a varied perception of climate change, with notable differences in their views on its causes, severity and impact.

The Chi-Square test helps us compare categorical variables (e.g., Gender, Course, Year of Study) to determine if students' perceptions of climate change significantly differ. A high Chi-Square value with a low p-value ($p < 0.05$) suggests a significant difference in perception based on categories like gender, course, or year of study. A high p-value ($p > 0.05$) means there is no significant difference, implying students across categories have similar perceptions.

From our Chi-Square test output, let's check if students' perceptions vary significantly:

Do you believe climate change is real?

Group	Chi2	P-value	Significant?
Course	2.27	0.99	No
Gender	3.00	0.22	No
Year of Study	42.97	0.000001	Yes

Table 3.1

- No significant difference by Course or Gender ($p > 0.05$) → Most students, regardless of their field or gender, have similar beliefs about climate change.
- Significant difference by Year of Study ($p < 0.05$) → Awareness levels change as students' progress in their studies.

What do you think is the main cause of climate change?

Group	Chi2	P-value	Significant?
Course	12.83	0.61	No
Gender	2.41	0.49	No
Year of Study	79.39	0.000000	Yes

Table 3.2

- No significant difference by Course or Gender → Students across different academic disciplines and genders have similar ideas about climate change causes.
- Significant difference by Year of Study → More advanced students may have different understandings of climate change causes compared to juniors.

Do you think climate change will impact your career or financial future?

Group	Chi2	P-value	Significant?
Course	1.55	0.91	No
Gender	3.36	0.07	No
Year of Study	5.94	0.20	No

Table 3.3

- No significant difference across Course, Gender, or Year of Study → Students generally share the same level of concern regarding how climate change will affect their careers.

B] Hypothesis 2

H0 - Exposure to educational institutions, social media, and peer discussions does not significantly influence students' perception of climate change.

H1 - Exposure to educational institutions, social media, and peer discussions significantly influences students' perception of climate change.

The Chi-Square test helps us understand if sources of information (such as social media, educational institutions, and peer discussions) significantly affect students' perception of climate change. A low p-value ($p < 0.05$) suggests a significant

relationship, meaning exposure to these sources influences perceptions. A high p-value ($p > 0.05$) suggests no significant relationship, meaning students' perceptions are not heavily influenced by these sources.

Influence Factor	Chi2	P-value	Significant?
Where do you get most of your information about climate change?	56.88	0.0043	Yes
Do you think educational institutions provide enough awareness about climate change?	2.32	0.6766	No
How often do you discuss climate change with your peers?	3.41	0.9061	No

Table 3.4

- Significant difference based on Information Source ($p < 0.05$) → Students' beliefs about climate change are strongly influenced by where they get their information.
- No significant difference based on Educational Institutions and Peer Discussions ($p > 0.05$) → These factors do not seem to play a major role in shaping beliefs about climate change.

C] Hypothesis 3

H0 - There is no positive correlation between students' perception of climate change and their willingness to adopt sustainable behaviors.

H1 - There is a positive correlation between students' perception of climate change and their willingness to adopt sustainable behaviors.

The Chi-Square test is used to determine whether there is a significant association between students' perception of climate change and their willingness to adopt sustainable behaviors. A high Chi-Square value with a low p-value ($p < 0.05$) suggests a significant correlation. A high p-value ($p > 0.05$) indicates no significant correlation, meaning that perception does not strongly influence behavior.

Do you believe climate change is real?

Sustainable Behavior	Chi2	P-value	Significant?
Lifestyle Changes	1.75	0.418	No
Participate in Initiatives	11.15	0.0038	Yes

Table 3.5

- No significant correlation ($p > 0.05$) with lifestyle changes → Students' belief in climate change does not necessarily lead them to change their everyday habits.
- Significant correlation ($p < 0.05$) with participation in initiatives → Those who believe in climate change are more likely to engage in environmental initiatives.

What do you think is the main cause of climate change?

Sustainable Behavior	Chi2	P-value	Significant?
Lifestyle Changes	6.89	0.075	No
Participate in Initiatives	4.3	0.231	No

Table 3.6

- No significant correlation ($p > 0.05$) with lifestyle changes or participation in initiatives → A student's understanding of climate change causes does not strongly influence their sustainable actions.

How much do you think climate change impacts the world and your own life?

Sustainable Behavior	Chi2	P-value	Significant?
Lifestyle Changes	1.19	0.88	No
Participate in Initiatives	9.44	0.051	No

Table 3.7

- No significant correlation ($p > 0.05$) with lifestyle changes or participation → Even if students perceive climate change as impactful, this perception does not strongly influence their willingness to adopt sustainable behaviors.

Do you think climate change will impact your career or financial future?

Sustainable Behavior	Chi2	P-value	Significant?
Lifestyle Changes	1.04	0.307	No
Participate in Initiatives	0	1	No

Table 3.8

- No significant correlation ($p > 0.05$) with lifestyle changes or participation → Students' concerns about career or financial impacts do not drive them to act sustainably.

5. Findings

In this research work, the researchers tried to find the perception of climate change among the college students in Pune city of Maharashtra. As per the analysis done based on the primary data collected by the researchers, there were important findings that came to notice. Different findings and observations are listed below:

1. There is variation in students' perception of climate change causes and reality across different years of study. However, Course and Gender do not show significant differences, meaning that academic background or gender does not strongly influence perception. This partially supports H1, as perception varies significantly by year of study but not as much by other factors.

One of the possible reasons could be:

- Higher-year students may have more exposure to climate-related topics or academic discussions.

2. Researchers examined how external sources affect climate change perception. Results showed a significant effect of information sources (like social media) but not of educational institutions or peer discussions. This suggests that informal sources (like the internet and media) shape climate change awareness more than formal education.

Some of the possible reasons could be:

- Social media and online platforms provide constant climate-related updates.
- Educational institutions might not emphasize climate change awareness enough.
- Peer discussions may not be frequent or in-depth enough to change perceptions

3. Perception does not consistently lead to sustainable action. Only one significant relationship was found: Those who believe climate change is real are more likely to participate in initiatives, but not necessarily change daily habits. No strong evidence that awareness leads to action in most cases.

6. Conclusion

This study aimed to explore how college students in Pune perceive climate change, focusing on their beliefs about its causes, severity, and impacts. It also examined the influence of educational institutions, social media, and peer discussions on students' awareness and understanding of climate change. Additionally, the study explored the connection between students' perceptions of climate change and their willingness to adopt sustainable behaviors.

The findings reveal that while most students acknowledge climate change as a significant issue, their understanding of its causes and effects varies. Educational institutions and social media play a pivotal role in shaping students' perceptions, emphasizing the need for more structured climate education and fact-based digital content. Furthermore, the study found that students who view climate change as an immediate threat are more likely to adopt sustainable behaviors, highlighting the strong link between awareness and action.

Despite these valuable insights, the study is limited by its narrow geographic scope and reliance on self-reported data. Future research could broaden the scope to include other cities and utilize mixed-methods approaches to explore behavioral changes over time.

In conclusion, this study emphasizes the importance of integrating climate education into higher education, leveraging social media for awareness campaigns, and

promoting peer-led sustainability initiatives. By improving climate literacy and engagement, students can be empowered to actively contribute to environmental solutions, effectively bridging the gap between awareness and tangible action.

Universities should go beyond raising awareness and introduce practical engagement strategies (e.g., sustainability rewards, peer-led initiatives). Education should focus on behavioral change rather than just climate literacy. H3 is only partially supported. While some students who believe in climate change participate in initiatives, overall perception does not strongly correlate with adopting sustainable behaviors. More efforts are needed to bridge the gap between awareness and action. The focus is needed on climate action inclusiveness.

The study is confined to college students in Pune, which may not be representative of students in other cities or rural areas, limiting the generalizability of the findings. A limited sample size may not fully capture the diversity of student opinions, reducing the robustness and reliability of the results. Reliance on self-reported data may introduce biases, such as social desirability bias, affecting the accuracy of students' responses. The study is cross-sectional and cannot track changes in perceptions over time, limiting insight into how views may evolve or respond to interventions. The study may not account for varying cultural, socioeconomic, and educational backgrounds, which could influence students' climate change perceptions. The research primarily focuses on perceptions and does not explore the

actual behaviors or barriers preventing the adoption of sustainable practices. The impact of external factors, such as media and global events, on student perceptions may not be fully captured.

The research can be expanded to other regions for a broader comparison of climate change awareness. Conducting long-term studies to track how perceptions and behaviors evolve can significantly improve our understanding of the issue.

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