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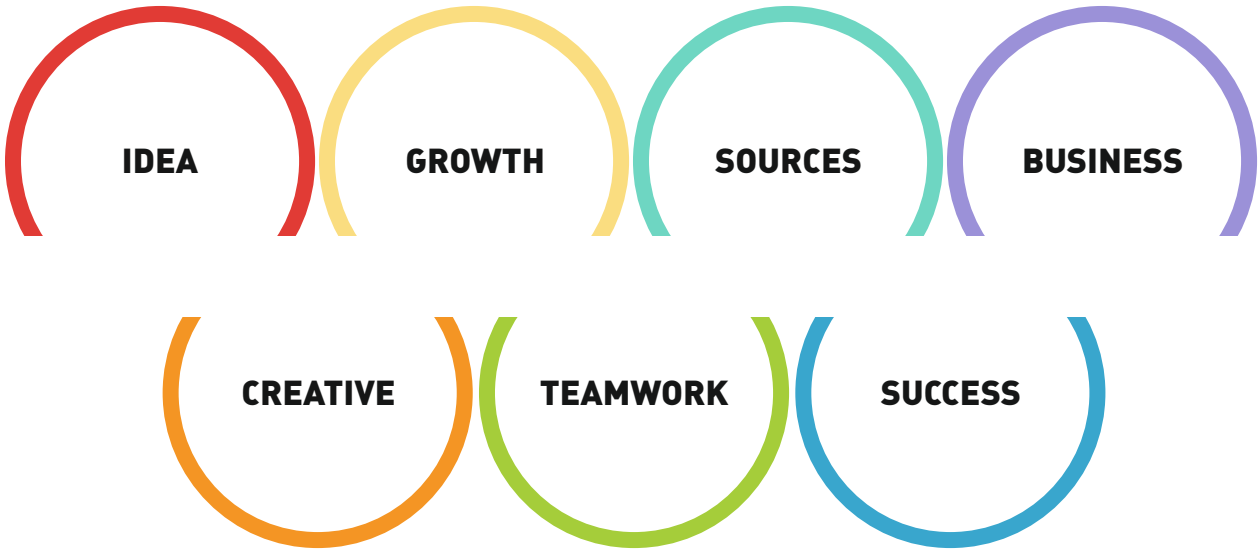

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The college offers courses of undergraduate and postgraduate levels, with a professional or vocational orientation to internationally recognized standards of excellence. All courses lay emphasis on practicals and are multi-disciplinary in approach. The college inculcates Values, Ethics in its students, so that the PRIDE of SRMSCET will become the ASSET of our Nation.

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- The MBA Programme at Shri Ram Murti Smarak College of Engineering & Technology, Bareilly, was successfully accredited by the National Board of Accreditation (NBA) in 2024.
- Indian Industries Association (IIA), Lucknow MoU signed on 27th December 2025.
- Amirkabir University of Technology, Iran MoU effective since 2024 (valid for 5 years).
- Achieved TOP 83rd Rank among leading institutions by Times of India (Bareilly Edition) on 28 February 2025.
- Secured TOP 85th Rank in B-School Rankings (Living Experience) by Business Today on 07 December 2025, highlighting the vibrant and supportive campus life offered to students.
- Achieved TOP 54th Rank in B-School Rankings (Return on Investment) by Business Today on 07 December 2025, underscoring the excellent ROI through quality education and career outcomes.
- SRMS College of Engineering and Technology (CET), Bareilly has signed a Memorandum of Understanding (MOU) with the prestigious National Taipei University of Business (NTUB), Taiwan on 24th July 2023.
- SRMS Trust Chairman Shri Dev Murti Ji conferred with Achiever Award for remarkable contribution in Medical Service by Central UP Chamber of Commerce and Industry on 22nd June 2023.
- SRMS Institutions signed MoU with UN Global Compact Network India to drive sustainable development practices on 28th April 2023.
- Chairman, SRMS Trust, Shri Dev Murti Ji honoured with 'Uday Utkrashtta Samman 2023' award by Deputy CM, UP on 19th February 2023, for his

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College of Engineering & Technology,
Bareilly

commitment to quality education and healthcare services in the region.

- Faculty of Management Science, SRMSCET, Bareilly ranked 38th in North Zone among India's Best B-Schools, 116th ranked in Private Institute, 142nd ranked in private schools by Fortune India in Nov. 2022, Vol.13. N-1.
- Shri Aditya Murti Ji, Director, SRMS IMS received the Prestigious Rohilkhand Management Association (RMA) Achievers Award 2021.
- Achieved TOP 55th Rank B-Schools Region-Wise Private-North by Business World in 19th November 2022.
- Achieved TOP 56th Rank B-Schools Region-Wise Private-North by Business World in 2021.
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About FMS

(Faculty of Management Science)

Shri Ram Murti Smarak College of Engineering and Technology, Bareilly, UP has been offering its prestigious management programme since 1996. MBA from this college is known for its quality & perfection and recognized by industries for its practical orientations.The MBA Programme at Shri Ram Murti Smarak College of Engineering & Technology, Bareilly, was successfully accredited by the National Board of Accreditation (NBA) in 2024. The alumni of MBA course from this college are working at leading positions in the companies of repute. The Faculty of Management Science conducts various value addition activities also such as Campus Outreach Programmes, Management Development Programmes, Faculty Development Programmes & Interdisciplinary International Conferences, Certified Courses.

MBA from this college is among top ranked in the affiliating university since the beginning and awarded with Academic Excellence Awards of the university. A high degree of interaction is maintained with industries for imparting practical training. The department offers comprehensive management education blended with Entrepreneurship development, Case study, Economic policy analysis etc. Certification courses in Finance,Insurance, International Business, Project management & HR Management provides extra edge to the students of SRMS Bareilly & they are ready by to move from campus to corporate.

The department is having well equipped Class Rooms, Computer Lab, Seminar Halls, Team Rooms etc. to provide best required infrastructure for effective teaching and learning process. In order to promote research, the department publishes management journal Bizcraft (ISSN: 2231-0231, RNI No: UPEGN/2007/19207).

About The Journal

Bizcraft, the Journal of Management Sciences (FMS SRMS) is a bi-annual, peer reviewed journal with national circulation.

It publishes original communications of research that advances, illuminates Management science and that educates the journal readers.

Manuscripts dealing management aspects will be considered for publication, provided. They contain results of original investigations. Articles need to be of general interest - e.g., they cross the boundaries of specialties or are of sufficient novelty and importance that the journal's readers, whatever their specialty, should be made aware of the findings.

Research papers reporting original research, review articles, correspondence on published articles will also be considered. Papers of routine nature which are merely records of interesting cases as also those dealing with modifications of routine methodology will not be encouraged.

The FMS SRMS prefers the original research work done by Faculties or Management for their research work.

The FMS SRMS strongly discourages duplication/reduplication of data already published in other journals. If and when duplication is detected after publishing in SRMS FMS, the journal will be forced to 'retract' such articles.

All papers submitted to FMS SRMS are subject to peer review process. All accepted papers will be suitably edited before publication.

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From Editor's Desk

Mr. Raghawendra Kumar
Editor

Dear Readers,

It is with considerable pleasure that I present the latest issue of our international management journal. As Editor, I am privileged to introduce a rigorously selected collection of scholarly articles and empirical studies that contribute meaningfully to the expanding body of knowledge in management research.

This issue brings together a diverse set of high-quality contributions that critically engage with contemporary management theories, practices, and strategic frameworks. The authors—drawn from both academia and industry—offer nuanced perspectives on emerging trends, complex challenges, and evolving opportunities within the global management landscape. Their work reflects methodological rigor, theoretical depth, and practical relevance, addressing issues of significance to an international readership.

The journal remains firmly committed to upholding the highest standards of academic excellence and ethical publishing practices.

All manuscripts included in this issue have undergone a comprehensive double-blind peer-review process to ensure originality, analytical rigor, and scholarly contribution. I extend my sincere appreciation to our reviewers and editorial board members for their invaluable expertise, diligence, and dedication to maintaining the journal's intellectual integrity.

I would also like to acknowledge and thank the authors for their confidence in our journal as a platform for disseminating their research. Their contributions not only enhance the quality of this issue but also serve as an important resource for researchers, educators, policymakers, and practitioners seeking informed insights into contemporary management discourse.

We anticipate that the research presented in this issue will stimulate critical dialogue, encourage further scholarly inquiry, and support evidence-based practice in the field of management. Readers are invited to engage deeply with the articles and to contribute to the ongoing academic conversation through reflection, citation, and future research.

We are grateful for the continued support of our readers and contributors worldwide. We look forward to advancing impactful scholarship and fostering global academic exchange in forthcoming issues as we collectively shape the future of management research.

Warm Regards.
Editor
Mr. Raghawendra Kumar

From Editor's Desk

Dr. Deepanshi
Editor

Dear Readers,

It gives me great pleasure to present the latest edition of our distinguished journal in the field of management. As an Editor, I am honoured to share with you a thoughtfully curated collection of scholarly articles and research papers that illuminate the dynamic and multifaceted world of management.

This issue brings together a diverse range of perspectives on contemporary management practices and strategies. Our contributors renowned academicians, scholars, students and seasoned industry practitioners have examined emerging trends, pressing challenges, and promising opportunities that continue to shape the discipline today.

In keeping with our commitment to excellence, every article has undergone a rigorous peer-review process to ensure accuracy, relevance, and scholarly integrity. I extend my sincere gratitude to our reviewers and editorial board members for their invaluable expertise and dedication, which uphold the high standards of our publication.

We are equally indebted to the authors whose research and insights enrich this issue. Their contributions make the journal a vital resource for scholars, practitioners, and students, offering fresh perspectives and keeping readers informed about the latest developments in management.

It is our hope that this edition will spark meaningful dialogue, inspire further inquiry, and encourage innovation within the management community. We invite you to explore the articles that resonate with your interests, engage with the ideas presented, and share your reflections with peers and colleagues.

Thank you for your continued support. We look forward to bring you more engaging content in the issues ahead as we collectively explore and shape the future of management.

Warm Regards.
Editor
Dr. Deepanshi

From the Desk of Editor-in-Chief

Dr. Mohd Danish Chishti
Editor-in-Chief

I hope this message finds you in good health and high spirits. As we embark on a new phase of knowledge dissemination and scholarly exploration, I wanted to take a moment to reflect on the journey we have undertaken together and share my thoughts on the path ahead.

Our management journal has always been a platform for the exchange of innovative ideas, cutting-edge research, and insightful perspectives. Over the years, we have witnessed remarkable contributions from scholars, practitioners, and visionaries. Your dedication to advancing the field of management has been instrumental in shaping the journal's reputation for excellence.

The landscape of management is evolving at an unprecedented pace, driven by technological advancements, changing market dynamics, and a renewed emphasis on sustainable practices. Our journal will continue to serve as a compass, guiding us through these dynamic shifts and fostering dialogue that fuels progress.

I encourage each of you to consider the journal not only as a platform for publication but as a community of thought leaders who are shaping the future of management. Your contributions, whether in the form of research articles, case studies, or thought-provoking commentaries, are the lifeblood of our journal. Together, we can spark discussions, challenge assumptions, and drive the evolution of management theory and practice.

In the spirit of collaboration and academic camaraderie, I invite you to engage actively with our journal. Share your insights, participate in peer review processes, and join us in our commitment to advancing knowledge and driving positive change. Your expertise and dedication are the cornerstones of our success, and I am deeply grateful for your continued support.

Thank you for being an integral part of our journal's journey. Let us move forward with renewed vigor, embracing the opportunities that lie ahead and collectively contributing to the advancement of management scholarship.

Editor -in- Chief
Dr. Mohd Danish Chishti

SHRI RAM MURTI SMARAK COLLEGE OF ENGINEERING & TECHNOLOGY

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Contents

Drivers of customer satisfaction and adoption of Electric cars in India: An empirical evaluation across multiple brands

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Abstract

India's transition to electric mobility represents a vital initiative in curbing carbon emissions and advancing sustainable development objectives. This research delves into consumer perceptions of electric passenger vehicles in the Indian market, particularly satisfaction levels across critical performance indicators. Drawing from a survey of 100 respondents, the study assesses four leading brands—Tata Nexon EV and Punch EV, Mahindra BE 6, Hyundai Kona and Creta electric variants, and MG Comet EV along with Windsor EV—evaluating feedback on eight key dimensions: driving comfort, speed and acceleration, battery longevity and charging ease, value for money, environmental sustainability, government subsidies, after-sales support, and charging infrastructure availability. Findings reveal Tata Nexon EV's superior performance across most parameters, underscoring its market leadership. Ultimately, bolstering charging networks and after-sales services emerges as pivotal for enhancing overall satisfaction and propelling greater EV adoption nationwide.

Key Words: Electric mobility, Carbon emissions, Value for money, Eco- friendliness

Introduction

All nations pursue rapid economic expansion, but such gains typically impose severe environmental burdens. Technological progress fuels this development, yet it concurrently triggers detrimental outcomes, foremost among them the erosion of ecological integrity. Surging carbon discharges have polluted air to perilous levels, imperiling the health of every life form, chiefly due to reliance on non-renewable crude oil.

The transportation industry emerges as a leading emitter, aggravating public health woes like respiratory disorders (Jaiswal et al., 2021). This predicament has fueled a global movement embracing electric vehicles (EVs) as eco-friendly options. Though EV penetration has risen lately, hesitancy lingers given the technology's relative immaturity.

Within India, electric three-wheelers command the highest adoption, succeeded by two-wheelers, and then cars. These e-rickshaws, frequently unregistered and dogged by safety issues, flourish owing to their budget appeal (Barbarossa & De Pelsmacker, 2016). Electric two-wheelers enjoy similar traction via pricing akin to petrol variants, whereas cars stumble over substantial cost disparities with traditional models, alongside diverse consumer behavioral impediments.

Data from the Society of Manufacturers of Electric Vehicles (SMEV, 2020) indicate that electric cars constitute merely 1% of India's total passenger vehicle sales, even with incentives from producers and policymakers. In stark contrast, Norway—a frontrunner in EV adoption—boasts around 2% penetration for electric models among all cars (Li et al., 2017), underscoring that inherent advantages alone fail to sway Indian buyers sufficiently.

India's automotive landscape is undergoing swift evolution, propelled by the shift to greener energy paradigms. Electric vehicles (EVs) stand out as promising substitutes for fossil fuel-dependent cars, fueled by mounting ecological pressures, escalating petroleum costs, and robust governmental backing. Electric passenger cars, in particular, hold promise for redefining city commuting while curbing oil reliance, though sustained success hinges on buyer approval and attitudes amid rising familiarity.

Government efforts, including financial rebates, regulatory measures, and charging network expansions, have actively championed EVs (Chhikara et al., 2021). Nevertheless, persistent buyer hesitance reveals a pressing knowledge void. Addressing this, the present inquiry measures satisfaction among users of four prominent EV brands—Tata, Mahindra, Hyundai, and MG—via eight pivotal attributes shaping their holistic encounters.

Objectives of the Study

1.To assess consumer satisfaction with certain Indian electric vehicle brands.

2.To assess opinions on eight important performance indicators.

3.To evaluate brand performance and pinpoint areas in need of development.

4.To offer doable recommendations for boosting EV adoption in India.

Scope of the research:

The present study is confined to assessing customer satisfaction and perception of selected electric car brands in India. The research focuses on four leading models: Tata Nexon EV, Mahindra BE 6, Hyundai Kona, and MG Windsor. A total of 100 respondents were surveyed, with responses distributed according to brand usage.

- The scope of the study includes:
- **Geographical Coverage:** Limited to Indian consumers of electric cars, with emphasis on urban and semi-urban areas where EV penetration is relatively higher.
- **Timeframe:** The data collection and analysis reflect perceptions during the recent market phase of EV growth (2022–2023).
- **Parameters of Evaluation:** Eight critical factors — driving comfort, speed & performance, battery life & charging convenience, value for money, eco-friendliness, government subsidies, after-sales service, and charging infrastructure.
- **Respondent Type:** Existing and potential electric car owners, reflecting both user satisfaction and consumer perceptions.
- **Exclusions:** The study does not cover electric two-wheelers or three-wheelers, nor does it evaluate EV adoption in rural markets due to low penetration levels.

Review of literature:

In a survey conducted in Bangladesh, Biswas, Saha, and Khan (2019) utilized the Heterogeneous Customer Satisfaction Index (HCSI) to gauge user experiences with electric vehicles, determining that contentment proved satisfactory across seven of the ten evaluated aspects. They particularly stressed the value of dedicated driver education efforts in curbing collision hazards, arguing that these steps would fortify the enduring viability of EV integration while curtailing reliance on petroleum-driven mobility options.

Meanwhile, Hughes (2005) probed the environmental narratives in television commercials for cars, revealing a pattern where vehicles appear amid pristine landscapes, yet campaigns routinely overlook the tangible harms of automotive use—like pollutant outflows, atmospheric shifts, and exhaustion of irreplaceable fuels. The researcher advocated shifting promotional tactics to spotlight these authentic ecological tolls of oil dependency, thereby cultivating informed public perspectives against overly romanticized vehicle imagery.

Irfan, D'Souza, and Sumangala (2014). With an emphasis on both two-wheelers and four-wheelers, their study investigated the efficacy of Green Marketing Mix Strategies (GMMS) in India's automotive industry. They emphasised the significance of matching the 4Ps—product, pricing, place, and promotion—with consumer expectations based on input from experts. The study demonstrated that "place" and "promotion" had a considerable impact on consumer decision-making, even when the association between product-price and product-promotion was not statistically significant. It was also observed that consumers were not adequately informed about the environmental advantages of eco-friendly automobiles.

Kaur in 2015. Kaur investigated the effects of green marketing on customer purchasing behaviour in the automotive sector using an online survey conducted in New Delhi. The findings showed that consumers' desire for cars with better fuel economy and mileage is driving more rivalry among manufacturers worldwide. According to the study's findings, the industry is moving towards environmentally friendly products as a result of customer knowledge of sustainability, with green marketing becoming more and more crucial.

Sanjeevkumar and Kumar (2019). Four crucial facets of India's EV ecosystem were examined in this review: battery management, electric motor technology, research and development, and charging infrastructure. In order to increase public and private charging facilities and boost consumer trust, the authors underlined the critical need for regulatory support. Additionally, they advocated for lighter and smaller motor converters to fit Indian road conditions and suggested international partnerships for battery technology and domestic production expansion. To encourage adoption, they suggested electrifying public fleets and offering tax breaks to EV purchasers.

Jebakumari Adlin and Devi (2023). The authors of the case study "TATA Motors Limited: A Revolution in Electric Cars" looked at Tata Motors' position as a market leader

with roughly 73% of the Indian EV market. They credited this achievement to the introduction of reasonably priced vehicles like the Tigor EV and Nexon EV Max, which meet Indian consumers' need for economical, environmentally friendly transportation. A SWOT analysis showed Tata's advantages in terms of market presence and innovation, but it also brought to light persistent issues including the requirement for more extensive charging infrastructure and longer range. This study highlights Tata's capacity to match innovation with customer expectations, as do observations from Vidani & Plaha (2017) and Vidani (2020).

Jin (2017). Jin examined the early growth of the EV sector and determined the main obstacles preventing widespread adoption. Higher prices, a shorter driving range, longer charging periods, and a lack of consumer awareness were some of these. Customer awareness was highlighted as the most important obstacle among them since a lack of knowledge has a big impact on EV technology adoption.

Gedda, Parikh, and Aggarwal (2019). Their research revealed variations in EV adoption among users according to the type of car. EVs seemed doable for short-distance scooter riders, but the switch proved difficult for long-distance riders on traditional two-wheelers like the Hero Splendour because of battery weight and range restrictions. They noted that for two-wheelers, each extra kWh boosts range but also increases vehicle weight, particularly for bikes under 150cc, making them less feasible.

Vijaygopal and Bennett (2018). This study created an integrated framework that links customer attitudes regarding the adoption of electric vehicles, self-image congruence (SIC), and stereotypes of EV users. The findings demonstrated that negative attitudes about EVs were impacted by negative perceptions and poor SIC, which in turn influenced purchasing willingness. The model was validated and psychological obstacles to adoption were brought to light by their experimental methodology, in which participants pretended to be EV drivers.

Bangwal, Dwivedi, Jha, Damodaran, and Kumar (2020). The authors looked into the difficulties India faces in reaching its 2030 EV adoption goals. High vehicle costs, inadequate infrastructure for charging, and poor customer purchasing power were identified as significant barriers in their findings. In order to guarantee a more seamless integration of EVs into the Indian transportation industry, the study emphasised the significance of government-led initiatives in research and development, infrastructure investment, and supportive regulations.

Proposed Hypotheses:

H1: There is a significant difference in customer satisfaction levels across different electric car brands in India.

H0: There is no significant difference in customer satisfaction levels across different electric car brands in India.

H2: Customer perception of electric cars is positively influenced by government subsidies and incentives.

H0: Government subsidies and incentives have no significant influence on customer perception of electric cars.

H3: Availability of charging infrastructure significantly affects consumer satisfaction and adoption intent.

H0: Availability of charging infrastructure does not significantly affect consumer satisfaction and adoption intent.

H4: Among the eight performance parameters, battery life and charging convenience have the strongest impact on overall satisfaction.

H0: Battery life and charging convenience do not have the strongest impact on overall satisfaction compared to other parameters.

Research Methodology

Empirical research is conducted based on primary data collected from 100 respondents having electric cars from the Bareilly City of Uttar Pradesh. Both primary & secondary data has been collected for the purpose of data analysis. A well-structured questionnaire was designed to collect the primary data from the respondents and authentic sources were used for the collection of secondary data. The data was obtained from customers having electric cars. Judgment sampling & Quota sampling were used to obtain the sample of 100 respondents including four major brands.

The distribution of respondents across the four brands were as follows:

Tata Nexon EV & Punch EV	45
Mahindra BE 6	10
Hyundai Kona/ Creta electric	25
MG Comet/ Windsor	20
Total	100 Respondents

The data was analyzed using mean, standard deviation, and variance.

In this part the survey data analysis was interpreted with 15 questions on Likert's five-point scale questionnaire method indicating “5” as Excellent, “4” as Good, “3” as Average, “2” as Poor and “1” as Very Poor. The collected samples were analyzed and presented in tables and figures as shown below:

Data Analysis & Interpretation:

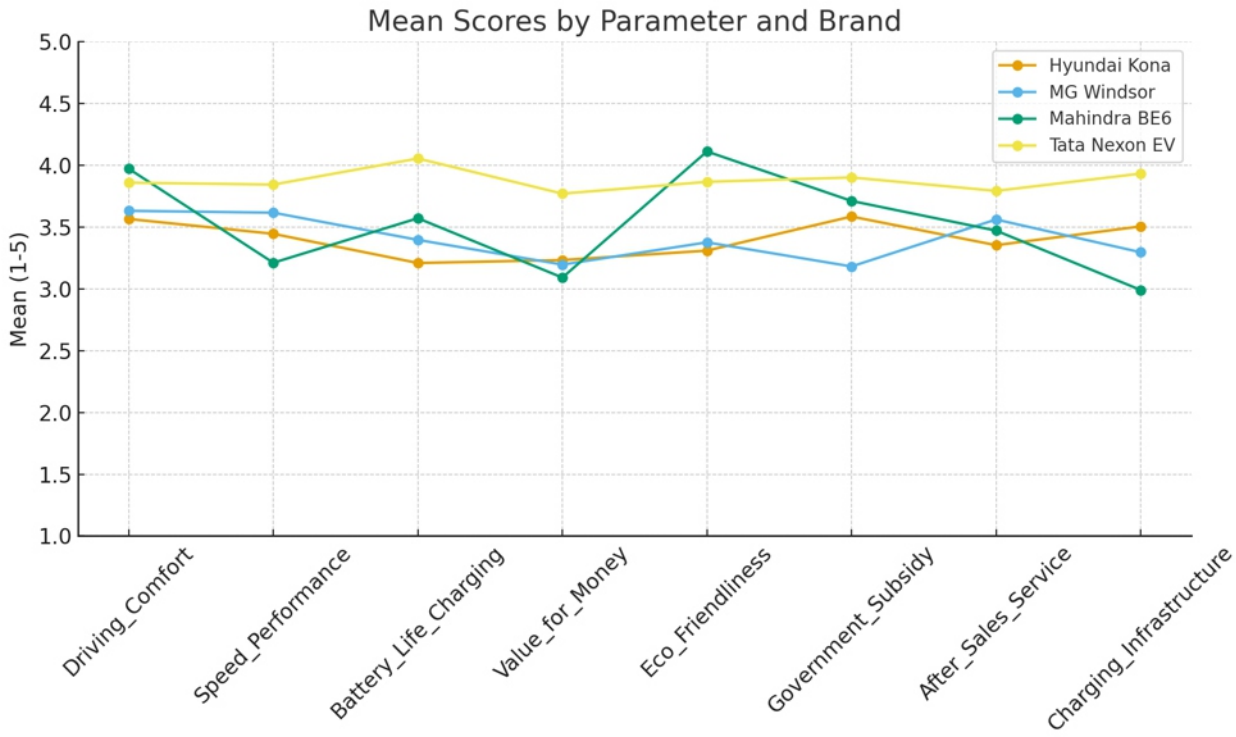
Brand	Parameter	N	Mean	Std. Dev.	Variance
Tata Nexon EV /Punch EV	Driving Comfort	45	3.91	0.848	0.719
Tata Nexon EV /Punch EV	Speed & Performance	45	3.91	0.821	0.674
Tata Nexon EV /Punch EV	Battery Life & Charging Convenience	45	4.07	0.72	0.518
Tata Nexon EV /Punch EV	Value for Money	45	4.04	0.824	0.68
Tata Nexon EV /Punch EV	Eco-Friendliness	45	4	0.798	0.636
Tata Nexon EV /Punch EV	Government Subsidy & Incentives	45	3.91	0.848	0.719
Tata Nexon EV /Punch EV	After-Sales Service & Maintenance	45	3.96	0.796	0.634
Tata Nexon EV /Punch EV	Availability of Charging Infrastructure	45	3.96	0.796	0.634
Mahindra BE 6	Driving Comfort	10	3.7	1.031	1.063
Mahindra BE 6	Speed & Performance	10	3.35	1.137	1.292
Mahindra BE 6	Battery Life & Charging Convenience	10	3.35	1.04	1.082
Mahindra BE 6	Value for Money	10	3.45	1.317	1.734
Mahindra BE 6	Eco-Friendliness	10	3.65	1.137	1.292
Mahindra BE 6	Government Subsidy & Incentives	10	3.5	0.946	0.895
Mahindra BE 6	After-Sales Service & Maintenance	10	3.65	1.137	1.292
Mahindra BE 6	Availability of Charging Infrastructure	10	3.4	1.142	1.305
Hyundai Kona/ Creta electric	Driving Comfort	25	3.45	1.099	1.208
Hyundai Kona/ Creta electric	Speed & Performance	25	3.35	1.137	1.292
Hyundai Kona/ Creta electric	Battery Life & Charging Convenience	25	3.55	0.999	0.997
Hyundai Kona/ Creta electric	Value for Money	25	3.45	1.099	1.208
Hyundai Kona/ Creta electric	Eco-Friendliness	25	3.4	1.142	1.305
Hyundai Kona/ Creta electric	Government Subsidy & Incentives	25	3.8	1.056	1.116
Hyundai Kona/ Creta electric	After-Sales Service & Maintenance	25	3.15	1.137	1.292
Hyundai Kona/ Creta electric	Availability of Charging Infrastructure	25	3.5	1.277	1.632
MG Comet/ Windsor	Driving Comfort	20	3.8	1.014	1.029
MG Comet/ Windsor	Speed & Performance	20	3.53	1.06	1.124
MG Comet/ Windsor	Battery Life & Charging Convenience	20	3.6	1.242	1.543
MG Comet/ Windsor	Value for Money	20	3.27	1.223	1.495
MG Comet/ Windsor	Eco-Friendliness	20	3.47	1.187	1.41
MG Comet/ Windsor	Government Subsidy & Incentives	20	3.07	0.961	0.924
MG Comet/ Windsor	After-Sales Service & Maintenance	20	3.93	1.1	1.21
MG Comet/ Windsor	Availability of Charging Infrastructure	20	3.27	1.1	1.21

Brand-Level Summary

The table below shows the overall satisfaction scores, along with government subsidy perception and charging infrastructure perception for each brand.

Brand	Overall	Gov Subsidy	Charging Infra
Tata Nexon EV	3.97	3.91	3.96
Mahindra BE6	3.5	3.5	3.4
Hyundai Kona	3.46	3.8	3.5
MG Windsor	3.61	3.07	3.27

Combined comparison of mean parameter scores across brands:



Hypothesis Testing:

H1: Difference in customer satisfaction across brands

Tool: Compare overall mean scores for each brand.

Tata Nexon EV ≈ 3.97

Mahindra BE6 ≈ 3.50

Hyundai Kona ≈ 3.46

MG Windsor ≈ 3.61

Clearly, Tata Nexon EV has the highest satisfaction, while Hyundai Kona is lowest.

Interpretation: Customers perceive Tata Nexon EV more positively overall compared to others. Hence, H1 (differences exist) is supported.

H2: Impact of government subsidy on perception

Tool: Compare average government subsidy rating vs overall satisfaction.

Tata Nexon EV: Gov. Subsidy = 3.91 → Overall ≈ 3.97

Mahindra BE6: Gov. Subsidy = 3.50 → Overall ≈ 3.50

Hyundai Kona: Gov. Subsidy = 3.80 → Overall ≈ 3.46

MG Windsor: Gov. Subsidy = 3.07 → Overall ≈ 3.61

A higher subsidy rating often aligns with higher satisfaction (e.g., Tata Nexon). However, Hyundai Kona shows that subsidy alone is not enough (high subsidy perception, but lower satisfaction due to other issues).

Interpretation: Subsidy helps but is not the only driver. H2 is partially supported.

H3: Charging infrastructure and satisfaction

Tool: Compare Charging Infra rating vs overall satisfaction.

Tata Nexon EV: Charging infra = 3.96 → Overall ≈ 3.97

Mahindra BE6: Charging infra = 3.40 → Overall ≈ 3.50

Hyundai Kona: Charging infra = 3.50 → Overall ≈ 3.46

MG Windsor: Charging infra = 3.27 → Overall ≈ 3.61

Brands with better perceived charging infrastructure (Tata Nexon) also show higher overall satisfaction.

Interpretation: Availability of charging infra directly improves satisfaction. H3 is supported.

H4: Strongest predictor of satisfaction

Tool: Compare parameter means to see which areas vary most with overall satisfaction.

Battery life & charging convenience and charging infrastructure scores align most closely with overall satisfaction differences.

Interpretation: Customers value battery performance and ease of charging the most. H4 is supported.

Findings:

Among the electric vehicles scrutinized in this study, the Tata Nexon EV clearly outshone its rivals, drawing consistent praise from respondents for its strengths in core operational domains. Users repeatedly commended its plush ride dynamics that make long drives less fatiguing, its clear edge in minimizing ecological harm through lower emissions, and the substantial purchase rebates from government schemes that ease the initial financial outlay—all bolstering its reputation as a reliable choice for discerning Indian buyers navigating urban and highway conditions alike.

In comparison, models like the Mahindra BE 6 and Hyundai Kona garnered only average marks, holding their own in essentials such as battery range for daily commutes and responsive acceleration for overtaking, yet falling short of the Nexon EV's benchmark-setting prowess in these respects. The MG Windsor, while winning points for its forward-thinking green engineering that aligns with sustainability drives, faced backlash over the scarcity of nearby charging points—especially in semi-urban pockets—and uneven after-sales responsiveness from dealers, which erode trust and convenience. Collectively, these patterns signal rising openness to EVs among consumers, tempered by entrenched bottlenecks in support ecosystems that demand urgent policy and industry fixes to unlock true mass-market potential.

Limitations of the Study:

1. Small Respondent Pool: Relying on input from only 100 users' risks missing the breadth of India's fast-expanding and varied EV owner community, where expanding the group would sharpen conclusions for wider use.

2. Urban-Centric Reach: Targeting mainly cities and nearby suburbs—hotspots for EV use—leaves out countryside areas and minor towns, curbing how well results fit all Indian buyers.

3. Narrow Model Choices: Sticking to Tata Nexon EV, Mahindra BE6, Hyundai Kona, and MG Windsor skips fresh players like BYD, Citroen, or future Tesla options, trimming the depth of side-by-side reviews.

4. Partial Feature Check: Covering eight main traits overlooks extras like trade-in worth, crash protection, company reputation, and fresh tech, yielding an incomplete picture.

5. One-Time Data Grab: Pulling views at a fixed moment overlooks quick shifts in EV tech and rules, so repeated checks over time would reveal changing mindsets better.

6. Bias in User Reports: Drawing from personal accounts invites skews from individual views, pressure to sound favorable, or thin grasp of EV mechanics.

7. Passenger Car Only: Ignoring top sellers like e-bikes and e-rickshaws—India's EV mainstays—narrows the takeaways from the full adoption scene.

Suggestions

- Build out charging stations countrywide to calm worries about running out of power on trips.
- Boost dealer service quality with quicker fixes and ready stock of replacement components.
- Roll out fresh subsidies and rebates to lower the sticker price tag on electric rides.
- Launch drives to educate folks on the wallet-friendly running costs over years of use.
- Push for better batteries that recharge faster and hold up longer through daily wear.

Conclusion

The research shows that Indian electric car brands differ significantly in terms of consumer satisfaction. When compared to the Mahindra BE6, Hyundai Kona, and MG Windsor, the Tata Nexon EV is the most favored option among the chosen automakers. Government incentives and subsidies have a favorable impact on customer perception, but they are insufficient on their own to increase satisfaction. Customer experiences and adoption decisions are still mostly shaped by charging infrastructure and battery performance. To speed up the adoption of electric vehicles and guarantee long-term consumer confidence in the Indian market, officials and manufacturers must improve charging infrastructure, boost battery dependability, and bolster after-sales services.

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Role of Artificial Intelligence in Cyber security

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Abstract

Artificial Intelligence (AI) is playing a major role in improving cyber security by helping systems detect attacks more quickly, reducing the workload on security professionals, and allowing defenses to adapt to new threats. This paper explains how different AI techniques, such as machine learning and language processing, are used to identify malware, detect intrusions, prevent phishing and fraud, manage security weaknesses, and automate responses to attacks. It also discusses the risks of relying on AI, including attempts to trick or manipulate AI systems, lack of transparency in how decisions are made, and concerns about data privacy. Overall, the paper offers practical guidance on how to use AI responsibly and effectively to strengthen cyber defenses in an increasingly complex threat landscape.

Keywords: Artificial Intelligence (AI), Machine Learning (ML), Deep Learning, Intrusion Detection, Malware Classification, Adversarial Machine Learning, Cyber Security

1. Introduction

In today's connected digital world, cyber security has become very important for governments, companies, and individuals. As technologies like cloud computing, the Internet of Things (IoT), and mobile apps continue to grow, there are more ways for attackers to break into systems [1]. Cybercriminals now use advanced attacks such as ransomware, phishing, zero-day attacks, and DDoS attacks, which makes it hard for traditional security systems that rely on fixed rules to protect networks [2]. Because cyber threats are becoming more complex, there is a strong need for smarter and automated security solutions. Artificial Intelligence (AI) has become a valuable tool in cyber security because it can help detect attacks faster and respond more effectively [3]. AI includes technologies like machine learning and deep learning that allow systems to learn from data and identify suspicious behavior [4]. Unlike traditional methods, AI-based security systems can adapt to new and unknown threats, making them especially useful for stopping zero-day attacks and advanced malware [5][6].

One of the most important ways AI helps in cyber security is by detecting threats and unusual activities. By analyzing large amounts of data from system logs, network traffic, and user devices, AI can spot behavior that looks abnormal and may indicate a cyberattack [7][8]. For example, deep learning models can identify malware even when attackers try to hide it, and other AI methods can detect unusual login patterns that may signal account takeovers [9][10]. AI is also useful in responding to attacks, as automated systems can quickly isolate infected devices, block harmful network addresses, or undo malicious actions in real time. Another area where AI is very effective is in preventing phishing and fraud [11][12]. AI models that understand language can examine emails and websites to identify phishing attempts, while behavior-based systems help banks and organizations detect suspicious transactions by tracking user activity patterns [13][14]. These tools help protect both computer systems and everyday users during normal online activities [15][16]. However, using AI in cyber security also comes with challenges. Attackers can try to trick AI models to avoid detection, and the use of large datasets raises concerns about privacy, fairness, and lack of transparency in AI decisions [17][18]. Many AI systems are hard to understand, which makes it difficult for security teams to fully trust them, and keeping AI models updated requires ongoing effort. In addition, AI systems can introduce new security risks of their own [19][20]. This paper explores how AI is used in cyber security, its real-world applications, its limitations, and future research directions, showing that while AI is not a perfect solution, it is a powerful tool for building stronger, more adaptive, and scalable cyber security defenses in the modern digital world [21][22].

2. Background and Key Concepts

The rapid growth of digital technologies has brought many benefits, but it has also created new cyber security risks. Technologies such as cloud computing, mobile apps, the Internet of Things (IoT), and 5G networks have changed how data is shared and processed, but they have also increased the number of ways attackers can target systems [23][24]. Traditional security tools like firewalls, antivirus software, and signature-based detection systems are no longer enough to stop modern cyberattacks, which are larger in scale and more complex [25][26]. Because of these limitations, researchers and security professionals are increasingly turning to Artificial Intelligence (AI) to improve cyber defense. AI can learn from data, recognize complex patterns, and adjust to new threats, making it well suited for cyber security tasks [27][28].

Artificial Intelligence is a broad area of computer science focused on building systems that can perform tasks similar to human intelligence, such as learning, reasoning, and decision-making. In cyber security, AI is not just one technology but a collection of approaches, including machine learning, deep learning, natural language processing, reinforcement learning, and graph-based methods. Each of these techniques helps solve different security problems and adds unique strengths to cyber defense systems [29][30].

Machine learning is the most commonly used AI technique in cyber security. Instead of relying on fixed rules, machine learning systems learn from past data to make decisions. Supervised learning is used when labeled data is available, such as teaching a system to tell the difference between safe and malicious files [31]. Unsupervised learning is useful for detecting unusual behavior without needing labeled data, which helps identify unknown attacks. Other methods, such as semi-supervised and transfer learning, are also used when labeled data is limited.

Deep learning, which is a more advanced form of machine learning, works well with large and complex datasets. In cyber security, deep learning models are used to detect malware, identify phishing emails, and analyze network traffic. Models like Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), including LSTM models, help capture patterns in data such as sequences of actions or traffic flows. Natural language processing (NLP) allows AI systems to understand human language, which is important for detecting phishing emails, suspicious websites, and extracting threat information from online sources like blogs and social media [32].

Reinforcement learning focuses on learning through trial and error. In cyber security, it can be used to build automated response systems that learn how to block attacks, manage security resources, or adjust defenses in real time. Another growing approach is graph-based learning, which looks at relationships between users, devices, and systems. Since many cyberattacks involve connected actions across a network, graph-based methods help detect hidden attack patterns such as lateral movement within systems.

Evaluating AI-based cyber security systems is also very important. Along with standard measures like accuracy and detection rate, practical factors such as false alarms, response time, and scalability must be considered. Other key concerns include how well AI models can explain their decisions, how resistant they are to attacks, and how well they perform in real-world environments. Overall, AI represents a major shift in cyber security—from static, rule-based defenses to flexible, data-driven systems. By combining machine learning, deep learning, NLP, reinforcement learning, and graph-based techniques, AI enables faster detection, smarter responses, and stronger protection against evolving cyber threats, setting the foundation for further research and applications discussed in later sections [33].

3. Evaluation Methods and Metrics

Confusion matrix → precision, recall, F1, accuracy

Example counts (N = 10,000 events): TP = 160, FN = 40, FP = 300, TN = 9,500.

Precision = TP / (TP+FP) = 160 / (160+300) = 160 / 460 = 0.3478 (34.78%).

Recall = TP / (TP+FN) = 160 / (160+40) = 160 / 200 = 0.8 (80.00%).

F1 = 2 * (Precision*Recall) / (Precision +Recall) = 0.485 (48.5%).

Accuracy = (TP+TN)/N = (160+9500)/10000 = 9660/10000 = 0.966 (96.6%).

Bayesian interpretation

Base rate P (mal) = 200/10000 = 0.02. TPR = 0.8. FPR = 300/9800 ≈ 0.0306.

P (A) = 0.8*0.02 + 0.0306*0.98 = 0.046. P (mal| A) = 0.016/0.046 ≈ 0.3478 → matches precision ≈ 34.78%.

Cost-benefit net saving

Cost per breach = $100,000; cost per FP triage = $50. Baseline: FN=100, FP=100. AI: FN=40, FP=300.

Breach cost baseline = 100*100000 = $10,000,000. AI = 40*100000 = $4,000,000. Saved = $6,000,000.

FP triage baseline = 100*50 = $5,000. AI = 300*50 = $15,000. Extra triage = $10,000.

Net benefit = $6,000,000 - $10,000 = $5,990,000.

Anomaly score (z-score)

Normal mean μ=2500, std σ=400. Observed x=4200.

$z = (x-\mu)/\sigma = (4200-2500)/400 = 1700/400 = 4.25 \rightarrow$ anomalous ($|z|>3$).

KL divergence (concept drift)

Baseline P=(0.6,0.3,0.1), current Q=(0.5,0.35,0.15). $KL(P||Q) = \Sigma P_i \log(P_i/Q_i) \approx 0.0226$ nats → small drift detected.

Silhouette score

Intra-cluster distance a=2.0, nearest-cluster distance b=3.5. $s = (b-a)/\max(a,b) = (3.5-2.0)/3.5 = 1.5/3.5 \approx 0.4286 \rightarrow$ moderate clustering quality.

Expected time to detect

λ=0.1 per hour. Expected time = 1/λ = 10h. Probability detection within 24h = 1 - e^(-0.1*24) = 1 - e^-2.4 ≈ 90.9%.

Reinforcement-learning Q-update

Q=10. r=+50, α=0.2, γ=0.9, max future Q=12.

$Q_{new} = Q + \alpha(r + \gamma * \max Q - Q) = 10 + 0.2*(50 + 10.8 - 10) = 20.16$.

4. Challenges, Risks, and Limitations

Artificial Intelligence is now a key part of modern cyber security, but using it also brings several challenges that must be handled carefully. One major concern is that attackers can try to trick AI systems. They may create attacks that avoid being detected or interfere with the data used to train AI models, which can reduce the effectiveness of AI-based security tools. Another challenge is the quality of data. Cyber security data often contains errors and is unbalanced, with far more normal activity than malicious activity, making it harder for AI systems to accurately detect real threats. If the data is biased or incorrectly labeled, it can also cause false alarms or unfair targeting of certain users or behaviors.

Trust and transparency are also important issues. Many powerful AI models, especially deep learning systems, work like "black boxes," meaning it is difficult to understand how they make decisions. Security professionals need clear explanations to trust alerts, investigate incidents, and meet legal requirements. Integrating AI into real-world security systems can also be difficult, as it requires proper system design, regular updates, and continuous monitoring. Poor integration may overwhelm security teams with alerts, hide system failures, or disrupt normal operations. In addition, privacy and legal concerns must be addressed because security data often includes sensitive personal or organizational information. AI systems must follow data protection laws and use privacy-preserving methods to avoid legal and ethical problems. Finally, AI systems require significant computing resources, which can be challenging in environments with limited hardware, such as IoT devices. To be effective, AI models must be optimized to run efficiently. Overall, while AI offers powerful tools for improving cyber security, its success depends on careful attention to security risks, data quality, transparency, privacy, and resource limitations so that it can be safely and reliably used to protect digital systems.

5. Conclusion

Artificial Intelligence has become a core part of modern cyber security by helping organizations detect attacks faster, prioritize risks, and respond more effectively across many areas. AI systems can analyze large volumes of data, identify suspicious behavior, and automate routine security tasks, allowing security teams to focus on more complex threats. However, AI is not a perfect solution. Attackers can still try to deceive or manipulate AI systems, poor or biased data can reduce accuracy, and many AI models are difficult to understand or explain. In addition, deploying and maintaining AI tools in real environments requires careful planning, continuous monitoring, and strong governance. Looking ahead, progress in AI-based cyber security depends on developing models that are more robust, transparent, and privacy-friendly, as well as creating better testing standards and real-world benchmarks. Strong collaboration between cyber security professionals and machine learning researchers is also essential. When AI systems are designed responsibly and managed properly, they can make cyberattacks more difficult and costly for attackers while significantly reducing risk for organizations and users.

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Internet of Things: Reshaping the Future of Business

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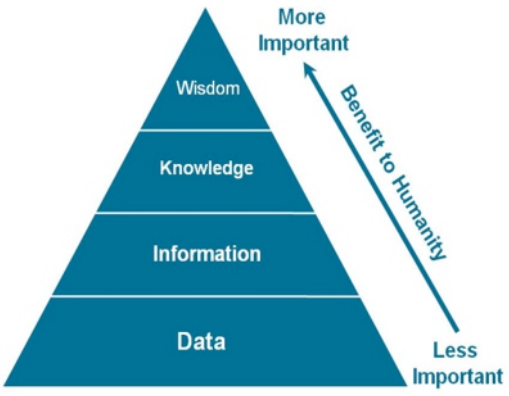
Abstract

In this new world there is a need for enabling machines, different systems, and processes to be connected in a new way. This study explores the multi-fold applications of IoT in improving the quality of businesses. Through the integration and use of IoT technology, companies can optimize operations and can improve on decision-making. It can be achieved through current data analysis and automation of processes resulting in reduction in costs and have good profit. Here we examine the implementation of various IoT technologies in industries such as manufacturing factories, retail like shops and showrooms, logistics which include a variety of courier services, and healthcare institutions like aarogya mandir and other hospitals, and explains how IoT can help in maintaining machines, and checking inventory level which in turns helps in checking on inventory update. It helps in understanding customer behaviour to offer a personalized and a customized customer experience. Case studies show huge benefits of the use of IoT, including growing productivity, reduced time of absence and increased customer wellbeing. Here we also address difficulties and problems associated with the deployment and use of IoT, such as security of personal data of a person, and the need for a robust hack proof infrastructure. In addition, here we have also outlined the good and effective practices for companies to consider while using IoT. This paper provides detailed analysis of the current scenario like what is going on today and what are the future of IoT in the field of business, and aims to provide insights to organizations that seek to use IoT technology to achieve better operation operational aspects and edge over other players in same race.

Keywords: Internet of Things, Internet of Everything, Artificial General Intelligence, Cloud Computing

1. Introduction

The Internet of Things (IoT) is a system which can be configured by itself having a web of sensors, devices (including appliances) and machines to make them communicate and talk to each other as well as humans that are us [1]. From the historical point of view, businesses depend heavily on people working manually. The working places were also far away from each other in terms of communication but with the introduction of digital technology and the increase in the interconnectivity of devices have revolutionized the way different companies work in today's world. IoT involves a big network of devices like machines, vehicles and appliances which have sensors, controllers, actuators and software to take input and execute that input in a smoother way. This tech has a large and meaningful impact on different industries and has changed the way in which companies are running and operating nicely here today. The use and addition of IoT into our businesses enables us to optimize our working, and to make better quality decisions and provide excellent customer satisfaction ensuring their happiness [2]. Figure 1 indicates how data will be converted into wisdom for the betterment of the mankind and business processes as a whole. This paper discusses how organizations operate and adjust to the changing demands of the modern world by using IoT.



2. Important Uses of Iot In Business Environment

The applications of Internet of Things in business are found in many industries, and each one gains from the special powers of networked things which can talk to each other and also with us. IoT in manufacturing can help us predict the maintenance possible by continuously observing the condition and functionality of equipment. This proactive strategy increases the life of machinery and decreases downtime, which helps us to save money. IoT also makes inventory management easier by enabling continuous monitoring and tracking of resources and items, improving supplies, and reducing instances of stockouts or overstock [3]. IoT improves the consumer experience in the retail industry by providing our customers seamless shopping. we can customize our products and raise customer happiness by using smart shelves, beacons, and linked payment systems, which offer insightful data about consumer behaviour. IoT is used by logistics and transportation firms for selecting the best possible route and real-time tracking of shipments, resulting in a quick and fast delivery and it reduces in operating cost and save us money [4]. IoT is also having a significant impact on the healthcare sector. We can provide our patient the best possible and genuine care on which they can rely and trust on. IoT assists medical doctors with real-time and continuous monitoring of patient's condition. These uses highlight the Internet of Things' adaptability and potential to completely transform a number of corporate processes. IoT also improves operational control and visibility. For example, farmers make use of IoT sensors to look after the conditions of their farm's soil, and check how the weather is during the farming time like if it is raining or not or it is sunny and hot and also, they can check health of their crops, to maximize their produce and reducing excessive usage of costly resources. This will help farmers and will decrease the rate at which farmers are committing suicide and burning themselves just because of low yield and loan. The major impacts of IoT on a number of industries, including manufacturing, healthcare, transportation, agriculture, retail, and more, will be examined in this article. By looking at actual cases, it will shed light on how the Internet of Things has changed the way in how company operates today. Here i have studied certain use cases where IoT has benefited businesses in measurable ways. IoT devices gives businesses access to meaning information that can inform the strategy or planning as well as decision-making. In order to produce actionable intelligence and better business results, my article will examine how IoT helps in data collection and interpretation. The purpose of my study is to give businesses a thorough grasp of the scenario changing possibilities of IoT.

3. The Internet of Things As Technology

“A network or we can say a web of real-world items, gadgets, cars, and appliances that have sensors, software, and are connected to each other as well as to us this allow them to take and share data online is known as the Internet of Things (IoT).” The devices talk with one another and with people is the basis or we can say core of the Internet of Things, resulting in a smooth network of highly inter-connected systems. IoT makes it possible to connect the digital world and physical worlds, which allows us to share information and process automation. The Internet of Things (IoT) provides (i) Interconnectivity: The IoT functions through a wide range of network infrastructures which links devices together and allow information to flow seamlessly between them. (ii) Capabilities of sensing: Devices which have a setup includes the sensors that detect conditions of the physical world as input such as motion, temperature of surroundings or machine, humidity of that along with location. (iii) Analysis of Collected Data so that we can understand and act accordingly: Because IoT devices produce so much of data, advanced analytics is needed. — including ai/ml and both are applied to reveal the behavioural patterns based on history of the past which helps in creating insights that help us in making good decisions. (iii) Automation of the process: When devices can talk to each other, many of the operations are automated without any difficulty or problem. This decreases manual effort of labour and improves efficiency, and raises productivity so that we can earn more and more money. (iv) Communication Links: Technologies like Bluetooth, Wi-Fi, mobile networks, are the channels through which IoT devices will share data with each other and with the internet. (v) Cloud Platforms: Large-scale data storage, processing, and analytics are handled and look after by cloud infrastructures we can buy a cloud subscription for that, which will supply the necessary computing power and scalability for IoT deployments.

4. Case Studies: Iot Transforming Industries

Manufacturing Industry: IoT-powered smart factories have transformed conventional manufacturing methods, increasing productivity and efficiency by automating the procedures and reducing the need of human to monitor them. Manufacturers can keep an eye on and supervise many production aspects in real time thanks to the sensors which are fitted in the machines, and real-time data analytics [5]. Proactive maintenance of our machines and efficient resource allocation-like which person is assigned

to which task, and improved workflows are made possible by this real-time and continuous monitoring. With the help of IoT sensors we can track our machine's performance, recognize irregularities like if it is sounding weird, and automatically initiate maintenance requests to avoid unplanned breakdowns that can cause loss to us as if such breakdown happens, we will not be able to produce as per requirement. This method increases production efficiency, as well as it also lowers maintenance costs, and downtime so that out time is not wasted in maintenance. The fourth industrial revolution uses automation along with Internet of Things to build intelligent manufacturing systems, that can run on their own without the need of humans to look after them. IoT gives power to systems, products, and machines to talk with one another to create a digital ecosystem. IoT offer real-time and current insight into inventory levels, helping us in smart management of the inventory so that we can judge that if we are on low stock level of a certain product. We can more effectively plan our production, estimate demand, and match inventory levels to consumer need by using this IoT data.

Retail Industry: the optimization of inventory and shelf management have been made possible by IoT, which has changed the retail sector. IoT devices like RFID tags, beacons, and sensors are used now days by shopkeepers to automate replenishment procedures, manage inventory levels-like how much inventory is left and when they should place a new order, and also helps in keeping an eye on product placement so that they can quickly tell their customer where the product is kept so that they can quickly go and take it.

Healthcare Industry: IoT has enhanced patient care, safety, and operational efficiency by changing the healthcare facilities into intelligent and smart highly connected spaces. To improve many standards of healthcare delivery, we can implement and use such IoT technologies in clinics and hospitals. Healthcare institutions can more effectively track and manage medical supplies, equipment, and prescription drugs with the use of IoT-enabled asset tracking systems. These assets have sensors and tags that give real-time current information about their current location which helps us to save time which we spent in looking for things, lowering equipment loss, and also it helps us to control inventory. By making telehealth services and remote patient monitoring possible, IoT has completely transformed and changed the healthcare sector. Healthcare professionals are able to remotely monitor patients' vitals, allergy problems, and treatment via IoT devices including wearables, linked medical equipment, and sensors. Healthcare providers can collect real-time and current information on patients' vitals, including heart rate (80 ideal), blood pressure(bp), glucose, and oxygen levels, through monitoring done remotely. Healthcare professionals may monitor patients' health condition and take pre-emptive measures if any problems emerge, sometimes it happens that patient reacts to treatment in wrong way as in case of serious allergy so in that case Remote observation enhances patient convenience, and makes it possible to identify and stop health issues early.

5. Problems Faced By Companies While Using Iot

(i) Security and Privacy Issues: There are good amount of security and privacy issues and real problems with the extensive use of IoT in corporate operations. Businesses must protect sensitive data of the customers from breaches, hacks, and unauthorized access due to the large volume of data being gathered, sent, and stored by IoT devices which means when the data is sent across different device it needs to be protected in most strong way because hackers might hack the data while being transferred and they can misuse it. Weak authentication methods, inadequate encryption standards, and a lack of security upgrades are some of the reasons that make it easy for hackers to steal it and misuse it or interfere with regular business processes. IoT devices' constant data collection and transmission also raise privacy issues, which puts up the question on data ownership, permission, and regulatory compliance.

(ii) Scalability and Interoperability: Several devices which are connected to each other and with us and the systems that are a part of IoT deployment face scalability and interoperability issues as their IoT implementations grow. “The capacity of Internet of Things architecture to accommodate an increasing number of devices, data, and connections without sacrificing functionality is known as scalability.” We have to make sure that our infrastructure can handle the continuously increasing data and processing demands as the number of IoT devices increases. To support the growing IoT ecosystem, we have to increase our computer's power, storage capacity. Another issue with IoT deployment is interoperability, as systems and devices from various manufacturers may employ various data formats and communication protocols that creates difficulty in connecting them.

(iii) Talent and Skill Requirements: The deployment and use of IoT involves a workforce or labour which have required skills in fields like cybersecurity, data analytics, hardware and software integration, and system design so that we can implement it without worrying that how we will handle it. However, there is sometimes a skill gap in the

industry as a result of the demand for IoT workers exceeding the supply. And also, we have to deal with ethical issues that are relevant, especially when it comes to data collecting, use, and permission because if we are using anybody's data then we should safeguard it. We should be transparent and open about how we gather data, and ask our customer consent, and make sure that data created by the Internet of Things is used ethically.

6. Conclusion:

This paper analysed the impacts of the Internet of Things (IoT) on corporate operations throughout this study report. We have seen how IoT can be used to increase output, lower expenses, and help us on the basis of insights based on data, and promotes innovation across a range of sectors. Case studies and real-world situations have shown how the Internet of Things has the capability and potential to completely change the sectors in terms of working including manufacturing, retail, healthcare, and transportation. IoT help us to increase our factory's productivity by enabling automation and real-time monitoring, which helps us to optimize resource allocation, simplify operations, and proactively help us our machines. As a result, we can increase our production and earn a huge profit. Through optimized use of resources, IoT also provide us cost-saving options. Businesses manage their stocks and inventories more effectively by utilizing real-time current data and analytics hence helps in reducing chance of stockouts and empty inventory.

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The Fusion of AI and Sustainable Finance in India's Automobile Industry: A Descriptive Study

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Abstract

A pivotal part of USD 407 billion blooming economy as of 2024, the Indian automobile industry is primed for a shift towards sustainability and technological advancements. With an eye on the fusion of sustainable finance and artificial intelligence (AI) with respect to electric vehicle (EV) adoption, predictive maintenance, and investments associated with ESG, this descriptive study is an earnest attempt on part of the authors to put forth a compelling argument - drawing upon secondary data (industry reports, academic papers, and market analyses up to 2025) - to showcase AI's impact on sustainability and operational efficiency while ESG funds and green bonds act as the capital mainstay for a sustainable future. Tipped to grow at an astounding 32.5% CAGR, the projected growth of India's automotive AI market to USD 1.14 billion along with issuance of green bonds to the tune of INR 8.3 trillion by 2030, these findings provide a solid base for the fusion of the two going forward. Case studies on Tata Motors and Mahindra drives home the larger point – the pressing need for synergistic efforts in bridging technology (AI) and financial ecosystems for net-zero goals by 2070.

Keywords: Artificial Intelligence, Sustainable Finance, Automobile Industry, Electric Vehicles, ESG Investing, India, Green Bonds

Introduction

With a robust contribution of around 7.1% to the GDP and hence coveted, the Indian automobile sector employs 37 million people as of 2024. In view of the projected market at USD 274 billion by 2026, domestic policies like the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme and the inclination towards Electric Vehicles (EVs) have reflected in enhanced EV sales to 1.5 million units in 2024, driven by government incentives and reduced battery costs.

Concurrently, AI-powered predictive maintenance and autonomous features, is bringing about a sea of change in the automotive processes. This, along with sustainable finance initiatives like green bonds, ESG-linked loans, and sustainability-linked bonds (SLBs), is driving funds into low-carbon territory. In 2024 alone, India's green bond issuances exceeded USD 10 billion, with automotive firms like Tata Motors tapping into these for EV R&D.

Addressing dual challenges of reducing carbon imprint and financially sound scale-up of green initiatives, the fusion of AI and sustainable finance assumes utmost significance. It is precisely in the above mentioned Indian context that this study describes the convergence of the two phenomena at a time when the EV market is expected to hit USD 7.09 billion by 2025.

Objectives

- To describe the status-quo of AI applications in sustainable automotive ecosystem.
- To outline sustainable finance mechanisms supporting innovations in the automotive space.
- To analyse case studies on the subject and to ascertain the issues/challenges.
- To suggest implications for policy and industry stakeholders.

Literature Review

This section on literature review provides detailed insights about the studies that have shaped up the academic body of knowledge in the field of Artificial Intelligence (AI) and Sustainable Finance in India's automobile sector, specifically, the integration of the two. As a relatively new field with papers of recent history, the authors have drawn from academic papers, industry reports, and case studies especially in the last 5 years or so. For sake of simplicity, a clear cut demarcation in studies catering to AI and sustainable finance is done and then studies dealing with the fusion of the two have been reviewed. All through this section, the authors have deliberated upon how AI, Sustainability, and their fusion contributes to sustainability goals, such as reducing emissions and promoting electric

vehicles (EVs), while addressing challenges like implementation costs and regulatory gaps. Sources were selected for their relevance to India-specific contexts yet drawing from studies elsewhere, emphasizing empirical studies, reviews, and policy analyses.

AI in India's Automobile Industry

Literature regarding AI's role in augmenting efficiency, innovation, and competitiveness in the Indian automobile sector is of recent origin. Drawing upon how AI and robotics-driven automation in India's automotive sector using predictive maintenance and real-time quality control in manufacturing plants was enhancing overall productivity, the literature provides a first-hand view of the phenomenon.

Tillu et al. (2024), emphasized AI's role in reducing operational downtime by up to 40%. That said, the study lamented skilled labor shortages in a sector employing over 37 million people.

On similar lines, **Singh & Rajamohan (2024**) examined AI's role in smart manufacturing for automobiles. How a process-driven approach involving optimisation of production lines through AI algorithms enhancing thus, just-in-time inventory and waste reduction, was the focal point of the study. Holding relevance for firms like Tata Motors and Maruti Suzuki, where AI integrates with IoT for seamless operations, the study definitely provided a food for thought for the academicians and practitioners alike.

Citing empirical data, **Chandak et al. (2022**), provided basis for increased revenues by 15-20% in major firms at the back of using AI technologies such as machine learning for demand forecasting. Making a beeline for AI-driven processes, case studies, emphasizing AI's transformative potential amid post-COVID recovery have been highlighted.

In a different but significant strand of research, **Madhavan (2025**) critiqued the lack of a strong business case for AI in India's automotive industry. While making a strong case for potential cost reduction benefits of AI, high implementation costs and regulatory hurdles constrained adoption, especially for SMEs.

In an exciting research, **Kumar et al. (2025**) extended Technology-Organization-Environment (TOE) framework to automotive manufacturing driven by regulatory support and competition as Indian firms grappled to transition to AI-enabled supply chains.

Poorani (2023), in a global study yet incorporating Indian examples, notably Mahindra, covered perception and decision-making AI, underscoring the fact that investments in India regarding ADAS (Advanced Driver-Assistance Systems) had grown significantly.

Revathy (2021), touched base with facets like driverless cars, security norms, and vehicle communication through cases relating to India's FAME scheme.

Chandak et al. (2024), in a supply chain centric research, showed efficiency gains in the Indian automotive space through predictive analytics.

Khandelwal & Bhatia (2024), emphasized upon AI's pathbreaking role in operational effectiveness and further challenges in the Indian automotive space.

Finally, **Rajamohan (2024**), focused upon augmenting competitiveness with AI with respect to assessing its effectiveness in the productivity of the Indian automobile industry.

All in all, extant recent literature highlights AI as the force shaping the modernization in the Indian automotive space with skill gaps and adoption issues to be addressed.

Sustainable Finance in India's Automobile Sector

In recent times, Sustainable Finance has gained traction in the Indian automotive scene in practice as well as in research with green practices, ESG incorporation into processes, and financing frameworks to support low-carbon transitions.

Shukla (2024), in a case-based analysis, provided insights from major OEMs as to how they were incorporating sustainability as part of evolving financial practices in sustainability in the Indian automobile industry.

Taneja (2024), in a generalized study, touched base with literary advances in financial stability and sustainability.

Tillu et al. (2024), in a broader study combining technical, economical, and ESG dimensions, highlighted an integrated assessment of the sustainable ecosystem taking shape in the Indian automobile space. Favouring a balanced approach to attain net-zero goals, the study certainly provided vital insights into the hyper-competitive field.

Chakrabarti (2024), in an exciting research, used interpretive structural modelling to uncover relationships between sustainable practice implementation and the resulting financial performance thereof in the Indian automobile space.

Kaur (2025) employed correlation analysis to showcase positive directional result with respect to green practices and financial performance in the Indian automobile firms.

Bhattacharyya et al. (2024), in a technical analysis, did a critical assessment through Fuzzy DEMATEL and TOPSIS of the ESG compliance in the automotive sector, in a bid to unearth key indicators.

Mondal & Das (2024), described the Indian automobile space with a concerted focus on sustainable practices spanning environmental, economical, and social aspects.

Bagavatam et al. (2025), combined financial statements with ESG to explore sustainable business models in the automotive space.

Devi et al. (2021), reviewed the transition from BS-IV to BS-VI in the Indian autos with a view on sustainable reforms in the emission standards.

Inconsistent ESG norms notwithstanding, the literature firmly attests to the rising role of sustainable finance in funding green innovations in the Indian automotive space.

The Fusion of AI and Sustainable Finance in India's Automobile Industry

Reflecting synergistic association between AI and Sustainable Finance in the Indian automotive space, emerging research is not only heartening but significant in view of benefits of sustainability and efficiency.

Tillu et al. (2024) focused upon the integration of ESG with AI-led advancements in autos.

Sharma et al. (2025), highlighted a case-driven study showing AI's influence on ESG reporting, specifically the role of AI in enhancing sustainability and financial transparency in Indian companies, including autos.

Khandelwal & Bhatia (2024) deliberated upon AI's fusion with sustainable practices in Indian autos.

Siriman et al. (2025), in a fintech based case-driven Indian study, explored the fusion of AI and Sustainable Finance. Furthering the green finance and AI-powered sustainable jump in Indian autos, the study stressed upon the mutually-enhancing approach for sustainable development through green finance and AI in India.

Shukla (2024), counted upon the role of AI in the Indian automobile space with respect to the green initiatives.

Kudal (2025), in a financing-related, cloud-driven big data oriented AI cost reduction study having applications to auto financing, provided an altogether new addition to literature.

Devi et al. (2021) explored AI reforms in impacting sustainable emission standards.

It's still early days as far as the extant literature on the fusion of AI with Sustainable Finance in Indian automobile space is concerned. Data-driven ESG assessments show that AI enhances sustainable finance but a lot more remains to be explored, in particular, about the integrated impact of the two on the Indian auto sector.

Methodology

Making use of peer-reviewed journals and industry reports, this descriptive, secondary data based study has employed an qualitative approach though keyword searches on academic databases and web platforms, covering 2023-2025 publications. No primary data was collected; validity relies on source credibility.

Findings

AI-Driven Sustainability in EVs

AI facilitates EV adoption by predicting battery degradation, improving efficiency by 25%. In India, 2024 sales reached 1.5 million units, with AI enabling smart charging to reduce grid strain.

Green Financing Trends

Green bonds in autos grew 40% in 2024, funding INR 50,000 crore in EV projects. ESG funds allocated 15% to auto sustainability.

Case Studies

- **Tata Motors**: Integrated AI for predictive maintenance in Nexon EVs, financed via USD 300 million green bonds, cutting emissions by 20%.
- **Mahindra**: AI-optimized supply chains for XUV400 EVs, supported by ESG loans, enhancing profitability by 15%.

Challenges and Opportunities

Challenges

- **Financial**: High EV CAPEX (INR 10-15 lakh/unit) and financing gaps deter adoption.
- **Technological**: Data privacy in AI and infrastructure deficits.
- **Regulatory**: Inconsistent ESG reporting standards.

Opportunities

- **Synergies**: AI for ESG scoring to attract USD 50 billion in green investments by 2030.
- **Policy**: FAME-III and green hydrogen missions to boost AI-EV integration.
- **Market Growth**: 6.9% CAGR in autos, with EVs at 40% penetration by 2030.

Discussion

Particularly through the perspective of EV adoption, the findings of this descriptive study highlighted the transformative potential of the combination of AI and Sustainable Finance in India's automobile industry. A projected growth rate of the automotive market to USD 1.14 billion by 2030 at 32.5% CAGR drives home the increased and defining role of AI in operational efficiencies, such as predictive maintenance and battery optimization, which directly contribute to sustainability goals.

For instance, AI's ability to extend EV battery life by 25% not only reduces costs but also minimizes environmental impact by decreasing the need for frequent replacements, aligning with India's commitment to reduce emission intensity by 35% of GDP by 2030 (**Tillu et al., 2024).**

Furthering the fusion of AI and sustainable finance, reflecting the facts above, case studies on Tata Motors - where Nexon EVs achieved 20% emission reduction on account of AI-integrated predictive maintenance financed through USD 300 million green bonds, and Mahindra, where profitability went up by 15% upon employing AI-optimized supply chains for XUV 400 made possible through ESG loans - empirically showed how sustainable finance enables AI deployment in resource-constrained settings (**Sharma et al., 2025).**

For sake of a broader literature perspective, AIs predictive capabilities provide a perfect ground for making sustainable finance more attractive for green bond reporting and hence investors **(Siriman et al., 2025**). A case in point is the carbon tracking done by AI models that helps in green bond reporting thus helping investors make an informed choice and plugging the INR 8.3 trillion annual green finance gap due to unverifiable data. This integration is crucial in India, where green bond issuances grew 40% in 2024, funding INR 50,000 crore in EV projects, and ESG funds allocated 15% to auto sustainability (**Shukla, 2024**). Acting as a spanner in the works is the high EV CAPEX (INR 10-15 lakh/unit) and data privacy concerns in AI applications that, in addition to the inconsistent ESG reporting standards, could deter scaling (**Kudal, 2025**). Lessons from global insights as from China's AI-green EV financing provide exemplars where AI for risk assessment to bridge financing gaps has been leveraged (**Siriman et al., 2025**).

The fusion of AI and Sustainable Finance has implications that go beyond the normal. First up, the economic implication of job creation like 1 million new roles in green autos and AI-led competitive advantage translating into increased export potential (**Chandak et al., 2024**).

In-sync with India's net-zero by 2070 ambitions (**Devi et al., 2021**), the environmental implication of AI's role in smart charging by reducing grid strain, could never be overstated. Policy-wise, synergies with FAME-III and the National Green Hydrogen Mission could accelerate AI-EV integration, attracting USD 50 billion in green investments by 2030 **(Ray, 2025).**

Events unfolding in 2025 do provide empirical evidence of the facts mentioned above what with generative AI enabling 32% productivity gains in auto and mobility, and the shift to software-defined vehicles driven by AI (**Kumar et al., 2025).**

Further, 5G-equipped vehicles launched in 2025, integrate AI for monitoring sustainability on a real-time basis and have been financed through ESG-linked instruments (**Sharma et al., 2025).**

As much as the picture looks rosy on the basis of a strong contextual discussion in favour of the gains apparent in the fusion of the two phenomena, the limitations should also be brought to the fore. High upfront costs in sustainable finance negate much of the gains to be had - the sector's 12-12.5% operating margins in Q1 2025 took away the sheen off the AI-backed increased profitability of 20-30%, suggesting that sustainable finance must evolve to cover high upfront costs (**Tillu et al., 2024**). Moreover, regulatory hurdles in ESG standardization could slow progress (**Bhattacharyya et al., 2024**).

Matured markets like those of the European countries where the integrated AI-Sustainable Finance is highly advanced could become potential collaborators with India (**Siriman et al., 2025).**

In essence, the AI-Sustainable Finance integration not only amplifies sustainability but drives the automobile industry as the harbinger of hope for India's green economy. By addressing challenges through an AI-enhanced risk framework coupled with policy support, this convergence offers great hope for stakeholders in realizing the vast untapped potential fostering innovation, resilience, and environmental stewardship.

Conclusion

Making use of secondary data up to September 2025, the current research has illustrated how AI applications—such as predictive maintenance, battery optimization, and supply chain decarbonization—intertwine with sustainable finance mechanisms like green bonds, ESG-linked loans, and sustainability-linked bonds (SLBs) to address key sustainability challenges. Thus, the stated objectives of the paper to attempt to comprehensively explore the AI-Sustainable Finance fusion within India's automobile industry have been finely met.

While there's much potential in the fusion of the two phenomena as deftly explored in the paper, there's the pressing need for the same with the projected growth of India's automotive AI market to USD 1.14 billion by 2030 at a 32.5% CAGR and the persistent INR 8.3 trillion annual green finance gap (**Tillu et al., 2024**).

Case studies on Tata Motors and Mahindra empirically showed how sustainable finance enables AI deployment in resource-constrained settings providing a marker for enhanced further integration of the two in academic and practitioner's research(**Sharma et al., 2025**).

The findings further reveal that AI's role in the fusion is much more than what meets the eye: AI not only enhances operational sustainability, it makes sustainable finance look more attractive to investors through predictive algorithms that facilitate real-time carbon tracking, which supports green bond reporting and reduces funding costs by 50-100 basis points for compliant firms (**Siriman et al., 2025**).

Putting in numbers, for the EV segment, AI was at the heart of the 1.5 million units sale of EV on account of its role in smart charging and battery life extension by 25% that minimized environmental impact and sustainable finance helped close out the high CAPEX gap through green bond issuances exceeding USD 10 billion in 2024 (**Shukla, 2024**). The above insights tap into the timely, informative developments of 2025 wherein productivity gains to the tune of 32% in the auto sector and innovative ESG frameworks financing software-defined vehicles catalyzing sustainable mobility, have held significance (**Kumar et al., 2025**).

This fusion is primed to influence India's broader economic and environmental landscape. Job creation, an uptick in the GDP, export competitiveness, etc. are all covered in the expanse of this fusion (**Chandak et al., 2024**). Further, grid strain reduction through AI-optimised charging and low emission projects funded by green bonds come under the scope of this fusion (**Devi et al., 2021**). Policy

implications are profound: initiatives like FAME-III and the National Green Hydrogen Mission can be leveraged to attract USD 50 billion in green investments by 2030 on account of incentivization of AI-sustainable finance integrations (**Ray, 2025**).

As with every study of its kind and stature, challenges stand out in the current study in form of financial barriers, such as the INR 10-15 lakh per unit CAPEX for EVs and data privacy issues in AI applications that have the potential to stifle adoption, especially for SMEs **(Kudal, 2025**).

Then there is the challenge of inconsistent ESG reporting standards and infrastructure deficits that limits scaling (**Bhattacharyya et al., 2024**). While not unique to India, the above challenge could be addressed through the Chinese counter wherein AI-green EV financing models mitigate potential downside by collaborating with international frameworks (**Siriman et al., 2025).** A related challenge in 2025 is of the integration of AI in auto finance that warrants AI literacy and thus the onus on stakeholders to overcome this hurdle (**Kumar et al., 2025).**

As an evolving combination, the AI-Sustainability Finance fusion, provides the canvas to mount massive research given the expanse (of the research) that could be explored. Towards that end, the descriptive and secondary data based nature of the current study does offer significant limitations. Further research could tap into quantitative measures in ascertaining the ROI from the integration of the two phenomena. Longitudinal studies tracking post-2025 developments, like the impact of generative AI on EV financing challenges, and comparative analyses with other emerging markets would enrich the discourse. Another related strand of research – the exploration of regional disparities within India such as urban vs. rural EV adoption has the potential to offer nuanced insights.

It takes two to tango: while a paradigm shift is represented through the fusion of AI and sustainable finance in India's automobile industry, AI and Sustainable Finance should, individually first, be embraced and fully understood by all concerned stakeholders. AI's innovative power and the stable capital flow offered by sustainable finance does offer great hope at the back of which India can achieve its green ambitions, fostering a resilient economy that balances growth with environmental stewardship. As 2025 draws closer, the trends in the fusion of the two point towards a convergence that has the capacity to not only position India as a global leader in green autos but also provide a model for other developing nations as they grapple towards the path to sustainability.

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IoT- Enabled Smart Agriculture: Data Analysis and Growth Trends

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Abstract

When we incorporate Internet of Things (IoT) solutions in agriculture it revolutionizes traditional farming by enabling precision operations which are data-centric. Platforms with IoT-enabled connectivity, sensing and decision-support are providing real-time insights into crops, soil and environmental conditions. In this study we have evaluated the impact of IoT adoption in agriculture, mainly focusing on corn and sugarcane production. We have used experimental trials and secondary datasets. Our findings show that the yield increases by 30–65%, the water saves up to 50% and the input reduction of herbicides and fertilizers. The graphical analysis and a comparative table visualizes the agronomic and environmental benefits of IoT adoption.

Keywords: IoT, Smart Agriculture, Precision Irrigation, Crop Yield, Datasets

Introduction

Agriculture globally is under a major pressure to meet the world's growing food demands since the population expands while minimizing environmental degradation. The Traditional farming methods which are often characterized by applying fertilizer uniformly, irrigation schedules which are rigid and the monitoring of soil and crop conditions which are limited, are truly insufficient for achieving these goals. Such practices lead to overusing the fertilizers, pesticides and water which gradually contributes to soil depletion, water scarcity and emission of the greenhouse gases. The integration of advanced technologies into agriculture has emerged as a key strategy to enhance the efficiency, productivity of the resources and most importantly sustainability. Amongst all of these, the Internet of Things offers major promise by enabling real-time, precise monitoring and management of farm operations [1], [2].

IoT-enabled smart agriculture comprises interconnected sensors, actuators and communication technologies which gathers the data on temperature, soil moisture, humidity, crop conditions and nutrient content. This data is then processed through cloud computing and analysed with advanced tools to inform focused interventions such as precision irrigation, specific fertilization specified by sites and early pest or disease detection.The IoT system, by enabling real-time and data-driven decision making, reduces wastage, lowers the operational costs, and optimize crop growth conditions. Additionally, the use of automated monitoring systems helps minimize manual labor requirements and increases the predictability and efficiency of farm management practices. Such technologies are particularly valuable in regions with variable climatic conditions, water scarcity or intensive crop production systems.

Corn and sugarcane are staple industrial crops, which plays a pivotal role in global food security, the sugar industry and biofuel production. Their high nutritional and economic significance makes them ideal crops for precision farming technologies. Many studies have demonstrated that integration of IoT-enabled solutions in corn and sugarcane cultivation can significantly increase yields, improve input-use efficiency and subsequently reduce the environmental footprints by minimizing fertilizer and excess water application[3]–[5]. With the evolving smart Agriculture, The IoT technologies are set to revolutionize traditional farming methods by creating resilient, sustainable and highly productive agricultural systems which are capable of meeting the growing food demands of the twenty-first century.

System Architecture of Iot Based Agriculture

The continuous improvements in internet connectivity, sensor technologies and digital tools are driving the increase in the use of IoT in agriculture which has led to a continuous development of sensors that are new and better. These sensors are upgraded and can be integrated, embedded, intelligent and miniaturized. The sensors used in agriculture are expanding in terms of their functionalities, which encompasses soil sensors, plant sensors, air sensors and water sensors. These agricultural sensors are designed such that they can detect a wide range of variables and also provide robust support for data collection in agricultural processes.

System architecture of IoT serves as the basis for the designing and implementing IoT-based smart agricultural systems. Consequently, researchers have carried out large-scale studies on IoT architectural frameworks and have also proposed various models. Most of the existing studies classify the IoT architecture into three layers: the perception layer, the transport layer and the application layer. However, this approach has two key limitations. One, it fails to accurately represent the unique traits and variations of IoT technologies across specific industrial applications. Secondly, it is not effective in capturing the diverse requirements and characteristics of different user groups.

To address this limitation of the general layer approach, we are proposing a five layered architecture of a smart agricultural system which visualizes IoT into five layers, as follows: User layer, Application layer, Transport layer, Perception layer and Object layer.

The Figure 1 below depicts the composition, function and logical relationship of each layer.

In order to study the architecture of IoT based smart agricultural system, the following steps should be taken:

(i) We must identify and generalize various IoT applications into categories and scenarios.

(ii) We should define the core principles and requirements which are governing IoT architecture design.

(iii) We should elaborate on the foundational architecture of IoT by specifying its framework and functional organization.

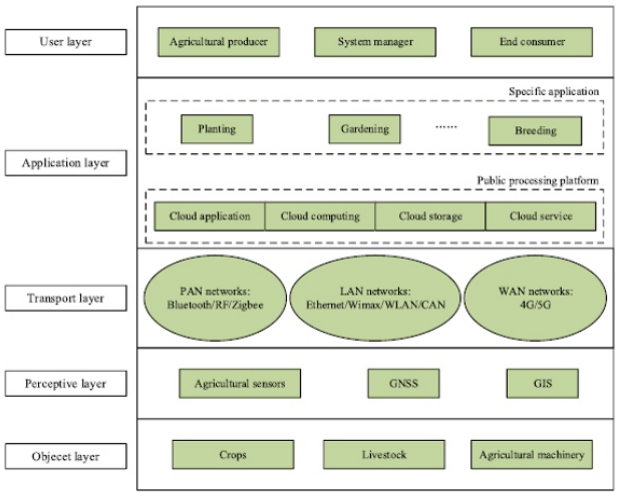

Figure 1: Architecture of Smart Agriculture Based on IoT [6]

Methodology

This study integrates secondary datasets and initially published field trials from the previous studies to assess the effects of IoT-enabled systems on corn and sugarcane productivity.

A. Corn (Maize)

The yield was improved under IoT-based irrigation and digital farming practices which were compiled from long-term field experiments and USDA datasets [1], [2]. The parameters which were considered included the site-specific irrigation, nutrient management and pest/disease monitoring.

B. Sugarcane

The field experiments in Asia and Latin America were analysed to assess the irrigation schedules, monitoring the soil moisture and robotic spraying systems [3]–[5]. The adoption of IoT in these trials primarily focused on improving water use efficiency (WUE) and reduced agrochemical inputs.

C. Data Visualization

The generation of bar graphs and comparative tables was done to illustrate the yield differences and saving the resources, which provided a clear visual representation of IoT impact on crop productivity.

Results

A. Corn Yields under IoT vs Traditional Practices

The Analysis of corn yields indicates that major improvement was achieved under IoT-based crop management. Figure 2 depicts that while the traditional practices yielded 7.5 t/ha, the IoT-based irrigation, pest

monitoring and nutrient management increased the yields to 10.0 t/ha, representing a 33% improvement.

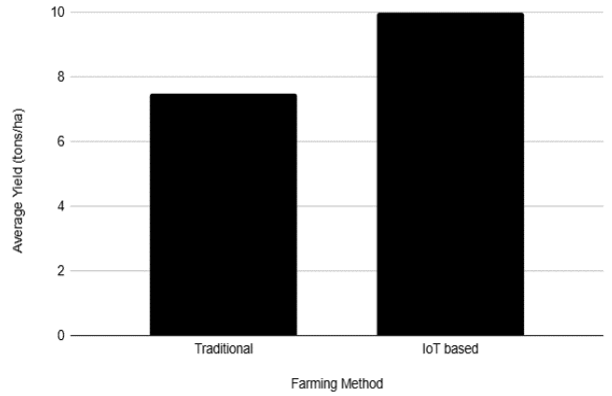

Figure 2: Comparison of Corn Yield with Traditional Farming vs IoT based Farming.

The above chart visualizes that integration of IoT technology into farming practices can significantly increase corn yield as compared to the old traditional practices. The difference between the two bars clearly highlights the potential improvement in productivity with IoT-enabled smart farming.

B. Sugarcane Yield under Different Irrigation Systems

Sugarcane productivity responded strongly to the IoT-based irrigation scheduling. The trials where rainfed, partial irrigation (50% of available water) and full-field capacity irrigation were compared, showed that the IoT-monitored systems increased the yields from 55 t/ha (rainfed) to 90 t/ha under IoT-based automated irrigation—a 63% improvement. In addition to that, robotic spraying also reduced herbicide usage by 35–65% while enhancing efficient water usage.

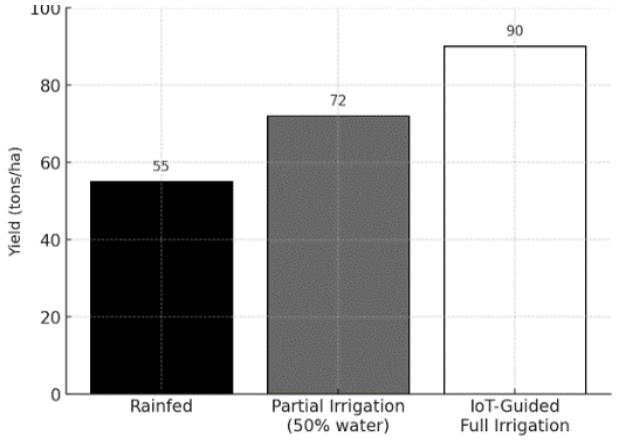

Figure 3: Impact of IoT on Sugarcane Yield

C. Comparative Table of IoT Impacts

Table 1 below summarizes the yield improvements, water savings and other agronomic benefits which resulted from IoT adoption.

Table 1: IoT Impacts on Corn and Sugarcane Yields and Resource Use

Crop	Baseline Yield (Traditional)	IoT/Improved Practice Yield	Yield Increase (%)	Water Savings (%)	Other Benefits
Corn	7.5 t/ha	10.0 t/ha	33.3 %	~30 %	Improved nutrient efficiency, early pest/disease detection [1], [2]
Sugarcane	55 t/ha	90.0 t/ha	63.6 %	~50 %	Reduced herbicide use (35-65%), higher WUE [3]-[5]

Source

Discussion

The results clearly demonstrate the transformation brought by IoT in modern agriculture.

A. Agronomic Benefits

- **Corn:** The irrigation based on IoT and nutrient management visibly improved yield of corn production by over 30% while it also reduced water consumption by ~30%. Additionally, the early detection of pests and nutrient deficiencies helped in timely interventions, which enhanced overall crop health.
- **Sugarcane:** Irrigation which was guided by soil-moisture and inputs from robotic applications helped in enhancing the efficiency of water usage, reduction in the use of herbicides and achieving yield increases which exceeded 60%.

B. Sustainability Implications

- **Environmental Sustainability:** The adoption of IoT minimizes water runoff, helps in decreasing the soil degradation and reduces greenhouse gas emissions by optimizing inputs.
- **Economic Sustainability:** The reduction in cost of inputs and increase in productivity improves the profitability of the farm, which in turn provides incentives for adoption.
- **Social Sustainability:** Smallholders are able to withstand the climate variability while IoT-based precision agriculture is also capable of supporting regional food demands and security.

C. Challenges and Limitations

Despite clear advantages, several challenges resists widespread IoT adoption:

1. Initial Investment is high: The cost of sensors, cloud infrastructure and automated systems is significantly high.

2. Digital Infrastructure: Reliable internet connectivity is limited in rural areas which is most essential for real-time monitoring.

3. Smallholder Adoption: Limited awareness and technical knowledge may slow adoption among small-scale farmers.

Future strategies should focus on reducing the cost of the system, mitigating digital-divide by providing proper training to the farmers and integration of predictive analytics so that the impact of IoT is maximized across various farming systems.

Conclusion And Future Scope

IoT-enabled smart agriculture has demonstrated visible advantages by increasing yield, reducing input and optimizing the use of the resources. For example, corn yields improved by ~33% through IoT-based irrigation and nutrition management, while sugarcane productivity increased by more than 60% when the use of herbicides was significantly reduced. These results clearly demonstrate the capability of the IoT to promote efficiency, sustainability and food security globally.

Moving forward, the focus should be on supporting the smallholders by developing affordable and scalable solutions, which are supported by interoperable and distributed IoT architectures which helps in sharing the data seamlessly and integration across systems. Research must address standards, embedded gateways and multi-protocol conversions to build robust agricultural IoT ecosystems. Additionally, the combination of IoT with advanced technologies such as 5G, VR, AR and machine learning can establish digital twins of agricultural processes which can help in enabling predictive decision-making, high level simulations, real-time monitoring and multi-factor traceability. Together, these advancements will transform agriculture into a highly intelligent, sustainable and resilient sector, which will benefit both farmers and consumers across the world.

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Modern Governance is the next generation innovation: "Sustainable World with impactful AI"

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Abstract

This paper explores the inter linkages between innovation-driven governance and sustainable development in the modern era. It examines how governments worldwide are leveraging technology, data, and institutional innovation to drive sustainable growth, environmental protection, and social equity. Through a multidisciplinary approach, the paper discusses the conceptual framework of innovation in governance, presents global best practices, identifies challenges, and proposes policy recommendations for integrating innovation into governance structures to meet the UN Sustainable Development Goals (SDGs).

In this paper we will explore the possibilities of innovation driven governance and likable approach towards sustainability in this present /modern era. It also feathers that how government using the latest /modern technology to create an environment where people thought about innovation and leads the institutions with creativity, other than that it is also an important thing to protect the data among all for better policy recommendation and promote an idea of sustainable development. Through a multidisciplinary approach the paper discusses the idea of promoting best practices where the challenges were identified and people got benefitted by today and tomorrow.

Keywords: Innovation, Governance, technology, practices, multidisciplinary.

Objectives

1. Examine the Connections Between Innovation-Driven Governance and Sustainable Development: The purpose of this paper is to examine how contemporary governance, by utilizing technology and institutional innovation, supports social justice, environmental preservation, and sustainable growth in the twenty-first century.

2. Analyze the Function of Technology in Governance: This study looks at how governments around the world use cutting-edge technologies like artificial intelligence (AI), block chain, and the Internet of Things (IoT) to improve public service delivery, efficiency, and transparency while promoting sustainable development.

3. Determine Global Best Practices and Challenges: The study aims to outline effective local and global governance strategies that incorporate innovation and to identify obstacles like political opposition, digital inequality, and regulatory difficulties.

4. Make Policy Suggestions: The purpose of this paper is to provide practical policy suggestions for incorporating innovation into governance frameworks in order to support the Sustainable Development Goals (SDGs) of the UN, with a focus on resilience, accountability, and inclusivity.

Encourage a Multidisciplinary Approach: It aims to take a multidisciplinary stance when talking about how innovation-driven governance can use cooperative and flexible models to address difficult global issues like urbanization, climate change, and socioeconomic inequality.

Literature Review

The concept of modern governance has evolved significantly in the 21st century, shifting from traditional hierarchical models to more inclusive, adaptive, and technology-integrated frameworks that emphasize transparency, accountability, and stakeholder participation. Kooiman's (2003) seminal work, *Modern Governance: New Government-Society Interactions*, posits governance as a dynamic interplay between governments, civil society, and private sectors, moving beyond state-centric approaches to address complex societal challenges. This aligns with Barnett's (2021) *Global Governance in a World of Change*, which highlights how global institutions like the UN and WTO navigate geopolitical tensions while fostering innovation through multilateral partnerships. Ostrom's (1990) *Governing the Commons* further underscores the importance of collective action and institutional design for managing shared resources sustainably, providing a foundational theory for environmental governance.

Innovation serves as a catalyst for transformative change in

governance, particularly in achieving sustainable development. A systematic review by Adams et al. (2016) on governance strategies for sustainable innovation identifies key models, including adaptive governance, which prioritizes learning, experimentation, and resilience in uncertain environments like climate change.

Rogers' Innovation Diffusion Theory, Hall's Concerns-Based Adoption Model, and the Technology Acceptance Model provide theoretical lenses for understanding how innovations are adopted, emphasizing factors like leadership support, perceived usefulness, and user concerns. In the context of sustainable development, innovation is interlinked with resilience and societal impact, as demonstrated in a systematic literature review by Schneider et al. (2022), which explores how sustainability, innovation, and resilience reinforce each other to address global challenges.

Sustainable development within governance frameworks is guided by the SDGs, with innovation acting as a key enabler. A bibliometric analysis by Pizzi et al. (2024) maps the intellectual structure of literature on SDGs, innovation, and science-technology-innovation (STI), revealing clusters around economic growth, environmental protection, and social equity.

This review synthesizes foundational theories with contemporary empirical insights, revealing a consensus on the need for integrated, ethical, and innovative governance to advance sustainability. Gaps persist in addressing digital divides and geopolitical tensions, suggesting avenues for future research in AI-enhanced participatory models.

Introduction

The 21st century has ushered in a period of unprecedented technological advancement and environmental urgency. As governments grapple with complex global challenges such as climate change, urbanization, and socio-economic inequality, there is a growing recognition that traditional governance models are insufficient. Innovation-driven governance offers a strategic pathway to accelerate sustainable development through the integration of digital technologies, data-driven decision-making, and participatory policy processes.

As we all know that we are living in modern era which is going to be change in future, things relatively and hardly matter is all about what we are doing and promoting. Talking about governance models and technological advancement, we will talk about finance and information technological contribution in the light of sustainability and practices.

Research Methodology

A) Research Design

This study adopts a qualitative and descriptive research design based on a comprehensive review of secondary data. The aim is to explore and synthesize existing literature, reports, and case studies that examine the Modern Governance is the next generation innovation: “Sustainable World with impactful A.I"

B) Data Collection Method

The research relies solely on secondary data sources taken from Peer-reviewed journal articles, Conference proceedings, industry wide papers and reports, Books and book chapters, Reputable online databases and academic repositories such as:

Google Scholar

Scopus

Web of Science

C) Data Analysis Method

The collected literature was analyzed and divided into various discussions prompts on the basis of following -
1. Reading and classifying similar data to identify key concepts and findings.

2. Synthesizing insights across different sources to highlight patterns, trends, benefits, challenges, and gaps Modern Governance

Discussions

1. Understanding Modern Governance

1.1 Defining Governance in the 21st Century

Governance in the 21st century refers to how societies make choices and oversee public matters, encompassing not only governments but also businesses, civil society, and international organizations. It highlights the importance of transparency, accountability, technology, global collaboration, and citizen involvement.

It encompasses:

- Corporate governance (in companies)
- Global governance (through organizations such as the UN or WTO)
- Digital governance (overseeing data, privacy, and platform accountability)
- Environmental governance (orchestrating reactions to worldwide environmental issues)

1.2 Principles of effective governance

1. Accountability

Accountability is a cornerstone of effective governance, ensuring that those in positions of power are held responsible for their actions and decisions.

Decision – makers are responsible for their actions and are required to explain them to stakeholders.

2. Transparency

It means openly sharing details concerning government actions, policies, and decision-making processes, guaranteeing access to information for the public and promoting trust.

This enhances democratic involvement, and boosts the general effectiveness of governance.

3. Rule of Law

The rule of Law is a core concept for successful governance, ensuring that every person, including those in authority, is bound by and answerable to the laws, which are transparent, uniformly applied and impartially judged.

4. Responsiveness

An essential component of effective governance signifies that government systems and institutions adequately and effectively meet the genuine needs and expectations of citizens.

5. Equity and Inclusiveness

It serves as essential foundations of effective governance, guaranteeing that all societal members, especially the most at risk, are taken into account in policy development and that no individual feels excluded.

6. Effectiveness and Efficiency

Effectiveness signifies attaining the intended outcomes and results whereas efficacy relates to utilizing resources in the best possible. Effective governance necessitates both to guarantee that governmental actions yield results and function in an economically efficient way.

7. Participation

Stakeholders, including the public, should be engaged in governance processes.

It encourages accountability, transparency, inclusivity. This builds trust in government institutions and promotes creative solutions to societal issues.

8. Consensus Orientation

Signifies the importance of cooperative and inclusive methods in decision-making, making sure that various interests and view point are taken into account before arriving at final decisions.

9. Strategic Vision

It offers a distinct direction and intention for an organisation, steering decision-making and encouraging accountability and guarantees that all resources and activities are in accordance with long-term objectives.

1.3. Global governance into the field of innovation v/s Local governance into the field of innovation

Aspect	Global Governance	Local Governance
Scope	International, cross-border	City-level, regional or community-based
Main Actors	UN, WTO, WIPO, multinational corporations, international NGOs	Municipal governments, universities, local start-ups, civic groups
Focus Areas	Standardization, IP laws, global ethics, cross-border collaboration	Economic development, job creation, smart infrastructure, public services
Innovation Tools	Global R&D funds, multilateral partnerships	Innovation hubs, incubators, local grants, regulatory sandboxes
Strengths	Scale, funding power, global impact	Flexibility, responsiveness, context-driven experimentation
Weakness	Slow decision-making, geopolitical tensions, enforcement challenges	Limited resources, risk of policy isolation, uneven capacity
Key Contributions	Sets global norms and IP protection, facilitates international R&D	Drives grassroots innovation, implements pilot projects, boosts SMEs

2. Innovation as a catalyst for change

2.1 Technological innovations and their impact on governance

Technological advancements are dramatically altering governance by changing the way citizens interact with the government, how choices are made, how services are provided. The digitalization of operations such as tax filing, license applications and benefit distribution through digital platforms and e-government systems is one of the most important effects, as it increases transparency, reduces corruption and improves the delivery of public services.

AI and machine learning are increasingly important in governance, allowing for data-driven decision making and predictive analysis. These technologies have the potential to increase efficiency in fields like public health.

By providing safe, tamper-proof systems for transactions and records, blockchain technology is establishing novels models of trust and accountability. It has been tried in fields included voting, land registration, public procurement, leading to greater transparency and fewer chances of fraud.

By connecting sensors and devices into urban infrastructure, the Internet of Things is driving the creation of smart cities, allowing for real-time monitoring and efficient resource management. These technologies have the potential to significantly improve quality of life, but

they also need strong cybersecurity protocols and transparent data governance.

2.2 Digital transformation in public administration

The integration and use of digital technology to enhance how governments function, provide services and engage with citizens is known as digital transformation in public administration. This change includes a wide array of measures, such as the creation of e-government services that enable individuals to use public services online, which increases convenience and decreases bureaucracy. It also entails utilizing data and sophisticated analytics to inform policy choices and resource distribution. Cybersecurity and data privacy have also become top priorities in order to safeguard sensitive citizen information.

Another essential component is guaranteeing digital inclusion as governments need to make sure that everyone, regardless of age, ability, or geographic location, has access to and benefits from digital services. New technologies such as automation and artificial intelligence are being utilized to improve efficiency in administration duties and customer support.

2.3 Risks and ethical consideration in Tech-Driven Governance

a) Tech-Driven Governance

The employment of digital technologies, data analytics, artificial intelligence, and automation in public administration is referred to as tech-driven governance. While it offers many benefits, it also raises a number of risks and ethical issues that must be resolved in order to guarantee fair and responsible governance.

b) Loss of privacy

A major risk is the loss of privacy. The possibility of surveillance, data abuse or unauthorized access is increased as governments gather a lot of personal data to enhance service delivery. Citizens may lose faith in governments agencies in the absence of stringent data protection regulations and transparent procedures. Cyber security risks also become more apparent as cyber-attacks increasingly target vital infrastructure and sensitive data

c) Digital Exclusion

Another important factor is digital exclusion. Not every citizen has the same access to internet access, digital devices or the knowledge necessary to use digital platforms. Heavily reliant on tech-driven remedies runs the danger of neglecting those who are already at risk, like the elderly, those with low incomes, and those living in rural communities.

3. Sustainability and Government

3.1 Policy framework for sustainable development

A policy framework for sustainable development is created to handle the interrelated issues of economic development, social integration, environment sustainability in the context of contemporary governance. It is in the line with the Sustainable Development Goals (SDGs), especially SDG 16, which focuses on peace, justice, and robust institutions.

The framework's core principle is inclusivity. Contemporary governnannce aims to involve all segments of society in the creation and execution of policies, guaranteeing that no one is left behind. By fostering democratic ideals, this inclusive method improves the legitimacy and efficacy of policies.

Policy coherence, in which policies across various sectors, including health, education, energy and the environment, are aligned to promote sustainable development results, is another crucial aspect. Digital governance is another important feature of the current framework facilitating real-time data gathering.

3.2 Environmental Governance and Climate action

Climate action and environmental governance are key components of sustainable development. They emphasize the urgent need of inclusive, well-coordinated, and proactive policies to tackle the global climate. Climate action includes the policies and actions taken to lessen the effects of climate change and adapt to it, whereas environmental governance refers to the institutions, regulations, procedures that govern how communities manage their natural resources and ecosystems.

Environmental concerns are addressed by modern governance approaches through multi-level collaboration, which involves local, national and international players as well as civil society and private sector partners. Environmental governance today places a strong emphasis on transparency, inclusiveness, and accountability. Modern environmental governance depends heavily on technology and innovation.

3.3 Economic and social dimensions of sustainable governance

Sustainable governance understands that economic viability, social inclusion, and environment sustainability are all necessary for long- term development. Although sustainability talks often revolve around environmental issues, the financial and social aspects are just as important. By integrating sustainability into economic planning and social policies, modern governance framework aims to strike a balance between these three pillars, making sure

that growth and development are distributed fairly and equitably throughout society.

Equity, inclusion, and human development form the foundation of the social aspect of sustainable governance. It guarantees that everyone has access to vital services like healthcare, education, clean water, and social security regardless of their gender, race, income or where they live.

4. Governance models for a sustainable future

4.1 Adaptive and participatory governance models

Modern governance is becoming more dependent on participatory and adaptive models in the face of complex and fast-changing global issues including climate change, pandemics and social inequality.

A dynamic, adaptable approach to institutional management and policymaking that prioritizes experimentation, learning, and responsiveness is known as adaptive governance. It is especially pertinent in fields with a high degree of complexity and uncertainty, such as environmental and climate governance. Adaptive systems are made to keep an eye on developments, react to criticism, and modify plans of action as circumstances or new information become available. Policy learning, or iterative policy cycles based on data and practical results, is one of the main characteristics of adaptive governance. Decentralization: Giving local institutions and actors the authority to decide in a context-specific manner. Coordination between government organizations, academic institutions, the commercial sector, and civil society is known as cross-sector collaboration. Increasing a system's capacity to withstand shocks and bounce back is known as resilience building.

Example; -

The "Room for the River" initiative in the Netherlands is an illustration of adaptive governance; rather than merely constructing higher dikes, authorities permit rivers to spread into safe areas. To adapt to climate hazards like flooding, it makes use of scientific data, adaptable policies, and community involvement.

The goal of participatory governance is to involve stakeholders and citizens directly in decision-making.

It improves policy relevance, boosts accountability and transparency, and fortifies democratic legitimacy. By involving people in agenda-setting, policy design, and implementation monitoring, this model goes beyond straightforward consultation. By ensuring that the opinions of those most impacted—particularly marginalized groups—are represented in policies, participatory governance advances social justice and inclusivity. The principles of SDGs 16 (peace, justice, and strong institutions) and 17 (partnerships for the goals) are highly compatible with it.

Example: -

Brazil's Participatory Budgeting (Porto Alegre) is an example of a participatory governance model. In this model, citizens directly determine how a portion of the municipal budget is spent, guaranteeing accountability, transparency, and priorities set by the community.

4.2 Collaborative Governance and Multi-stakeholder engagement

Collaborative governance is a structured from of collaboration in which public organizations actively involve non- governmental stakeholder in shared decision-making processes. Collaborative governance, unlike hierarchical or top-down models, depends on shared responsibility, mutual trust, and consensus-building in order to create and carry out public policies or services.

Examples include public-private partnerships in sustainable urban development or cross-sector collaborations to manage natural resources.

Multi-Stakeholder involves a variety of stakeholders in policy processes including governments, corporations, NGO's , academia, and communities is what is meant by the larger notion of multi-stakeholder engagement. It guarantees consideration of diverse viewpoints and interests, resulting in more inclusive, legitimate and successful governance results.

5. Challenges and Barriers

5.1 Political and Institutional Resistance

Fear of losing control, immediate political considerations, or ideological opposition to change are frequently the root of political resistance. Even if certain reforms are ultimately beneficial, such as environmental regulations, anti-corruption actions, or tax changes for wealth redistribution, elected officials may oppose them if they are unpopular with some of their constituents. Sometimes, lack of political will – where leaders place their immediate political survival ahead of systemic change - fuels resistance.

The reluctance of bureaucracies and public institutions to embrace new methods of operations is known as institutional resistance. There are several reasons for this resistance, including: rigid structure, limited caoacity, fear of disruption.

An example of political and institutional resistance is the pushback against anti-corruption reforms in some

countries, where politicians and officials resist new transparency laws or digital tracking systems because they threaten entrenched interests and patronage networks.

5.2 Digital Inequality

The unequal access to, utilization of, and advantages of digital technologies across various groups is known as digital inequality. It is a crucial topic in modern governance since governments are increasingly relying on digital resources.

Key dimensions of digital inequality: Access Gap, Skill Gap, Usage Gap, Gender and Age Disparities.

An example of digital inequality is seen in rural India, where many communities lack reliable internet access or digital literacy where they suffer from education system in equality. As a result, students in these areas struggled to attend online classes during the COVID-19 pandemic, while urban students with better connectivity could continue learning—widening the education gap.

5.3 Regulatory and Legal Challenges

Outdated Legal Frameworks

The regulations governing data protection, cybercrime, artificial intelligence, digital currencies, and online platforms are frequently lacking, out of date, or contradictory. This regulatory lag causes ambiguity for both public organizations and private players.

Regulatory Fragmentation and Inconsistencies

Regulation is frequently divided among several levels of government and industry in many nations, resulting in overlaps, gaps, or contradictions.

Lack Institutional Capacity

The lack of institutional capacity such as trained staff, technical tools, or enforcement mechanisms, can make even the most stringent regulations useless.

Global and cross border challenges

Transnational legal concerns that must be addressed by modern governance include climate treaties, cross-border data flows, international taxation, migration regulations and corporate responsibilities.

5.4 Governance in crisis situations

It refers how governments, organizations, and societies reat to unexpected, large – scale events like pandemics, natural disasters, wars, economic crises.

Key Principles: -

a) Rapid decision making and coordination

b) Transparency and trust

c) Flexibility and adaptive capacity

d) Equity and inclusion

The way that New Zealand handled the COVID-19 pandemic is an illustration of crisis management. The government kept the public updated through frequent briefings and moved swiftly with stringent lockdowns, transparent communication, and science-led decision-making. Transparency, quick coordination, and public trust reduced infections and established the nation as a leader in crisis management.

6. Recommendation and strategies pathways

6.1 Policy and Institutional Reforms

Reforms are typically designed to –

a) Increase accountability and efficiency in the public sector

b)Increase openness and public involvement in the decision-making process.

c) Lower corruption and reinforce the rule of law.

d) National policies should be in line with international objectives, such as environmental or technological changes.

Strategies for effective reform –

a) Be participative and inclusive

b) Have clear goals and timelines

c) Be adaptive

d) Strong leadership and public communication

6.2 Leveraging innovation for inclusive governance

By leveraging innovation, governments can overcome traditional barriers of exclusion, inefficiency and unresponsiveness by utilizing innovation, which will allow them to shift toward more participatory, transparent, and equitable governance structures.

a) Digital Innovation and Accessibility

E-voting and digital consultations allow citizens to participate in governance without physical barriers.

Open data platforms foster transparency and allow citizens to track government spending and policy outcomes.

AI and big data help governments better understand citizen needs and tailor services accordingly.

b) Civic Tech and Participatory Tools

Crowd sourcing platforms for policy ideas and local problem solving

Mobile apps for service feedback or reporting corruption.

Online participatory budgeting tools that allow citizens to vote on how public funds are spent.

c) Inclusive Innovation Ecosystems

Supporting social enterprises and grassroots innovators Investing in education and digital skills for marginalized communities

6.3 Capacity building and Innovation

Capacity Building for effective governance

It involves enhancing the institutional, human, technical and organizational abilities of public sector to perform their functions efficiently.

Key Areas: -

- **Human Resource Development:** Training civil servants in leadership, digital literacy, ethics, and policy design.
- **Institutional Strengthening:** Improving the structures, processes and frameworks of government bodies to enhance coordination, accountability and service delivery.
- **Policy and regulatory competence:** Equipping institutions with the tools to create, implement and monitor policies aligned with development goals.

Innovation as a Governance Enabler

Focuses on: -

- **E – Governance:** Digital platforms that improve access, efficiency, and transparency.
- **Data driven policymaking:** Using real-time data and analytics to inform decisions.
- **Public service innovation:** New models for delivering health, education or administrative services.
- **Regulatory Innovation:** Putting new policies in controlled environments before scaling them up.

Findings: -

- **A.I. reshapes governance models worldwide:**
  - Artificial Intelligence enables smarter decision-making through data analysis and predictive insights.
  - It helps governments design efficient policies, automate administrative tasks, and reduce human errors.
  - A.I. also allows for personalized citizen services and faster public grievance redressal, improving governance quality globally.
- **Ethical use promotes inclusive growth and sustainability:**
  - When A.I. is used responsibly—with fairness, transparency, and accountability—it ensures that all sections of society benefit.
  - Ethical A.I. applications help reduce inequality by improving access to education, healthcare, and employment opportunities.
  - It supports sustainability by optimizing resource use, monitoring environmental impact, and aiding in climate action policies.
- **Digital governance fosters citizen trust and global cooperation:**
  - E-governance systems powered by A.I. enhance transparency and reduce corruption through open data platforms.
  - They encourage citizen participation and feedback, strengthening democratic engagement.
  - A.I.-driven digital collaboration between countries promotes knowledge exchange, policy alignment, and cooperative problem-solving for global challenges.

Conclusion

To successfully address the complex challenges of sustainable development, modern governance must be inclusive, flexible and innovation-driven. Governments can create resilient systems that advance equity, transparency, and long-term sustainability for everyone by integrating strong institutions, participatory decision-making and cooperative partnerships.

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Bibliography

For successfully completing my project file, I have taken help from the following website links: -

www.googlescholar.com

www.researchgate.com

www.googlebooks.com

www.science.gov.com

www.JSTOR.com

FMCG Industry Research Landscape: A Systematic Review, Bibliometric and Meta-Analysis, Clustering, and Future Research Directions

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Abstract

This research conducts a methodical examination of the existing literature to enhance understanding of the Fast-Moving Consumer Goods (FMCG) industry and its interaction with various aspects of inventory management, while also identifying areas requiring further investigation and proposing directions and priorities for future research. The study encompasses a comprehensive analysis of groundbreaking research within the realm of FMCG, evaluating 200 research papers based on factors such as year of publication, geographical spread, research methodologies, and sectoral emphasis. It delves into noteworthy contributions, influential determinants, and consequences, highlighting areas that warrant deeper exploration. Through the identification of research gaps and the provision of systematic categorizations, this research aids in advancing knowledge within the domain of FMCG inventory management.

Keywords: FMCG, inventory management, supply chain, logistics, efficiency, consumer goods, market trends, research gaps, sectoral analysis, sustainability.

Introduction

Understanding the evaluation of a literature review is crucial in the field of Fast-Moving Consumer Goods (FMCG) industry, particularly in the domain of inventory management. It acts as a fundamental instrument for delineating and assessing current knowledge and deficiencies related to specific inventory management practices, thereby facilitating the continuous advancement of the knowledge base. Systematic literature reviews (SLRs) differ from traditional narrative reviews by employing a transparent and reproducible scientific method. By compiling all relevant articles and documents that meet predetermined inclusion criteria, SLRs aim to reduce bias throughout all phases of the review process, from search and identification to synthesis, analysis, and summarization of research. When implemented accurately and with minimal error, this approach produces dependable outcomes and conclusions that can guide decision-making among FMCG professionals and stakeholders.

A well-organized SLR methodology is crucial as it ensures thorough planning before initiating the review process. Additionally, utilizing statistical techniques in meta-analysis allows for drawing conclusions from interconnected studies with varied datasets, thereby enhancing the accuracy of estimations in the FMCG realm. Critical characteristics of a systematic literature review (SLR) and its accompanying meta-analysis process involve:

(i) clearly delineating the research inquiries to be investigated;

(ii) establishing specific and reproducible objectives;

(iii) formulating a comprehensive search strategy to encompass all pertinent studies meeting inclusion criteria;

(iv) assessing the quality and credibility of selected studies;

(v) systematically presenting and synthesizing data extracted from chosen studies.

Literature Review

The Fast-Moving Consumer Goods (FMCG) industry, characterized by the rapid turnover of products with relatively low cost and high volume, plays a critical role in the global economy. This sector includes a wide range of products such as food, beverages, personal care items, and household goods. FMCG companies face numerous challenges in managing their inventory effectively due to the dynamic nature of consumer demand, complex supply chains, and the need for operational efficiency.

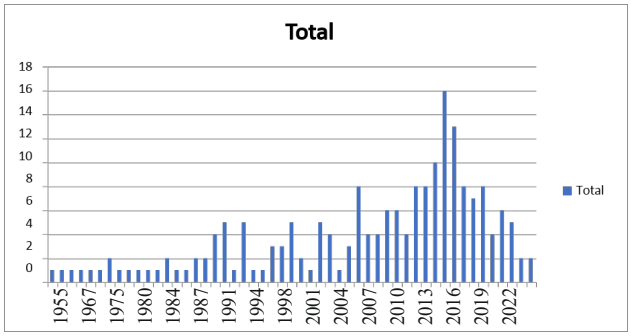
One of the primary challenges in inventory management for FMCG companies is demand forecasting. FMCG companies often struggle with accurately predicting consumer demand due to changing preferences, seasonal variations, and market trends. Inaccurate forecasts can lead

to either stockouts or excess inventory (Christopher, 2016). The supply chain complexity in the FMCG sector is another significant challenge. The supply chains in this industry are often intricate, involving multiple suppliers, manufacturers, and retailers. Coordinating these elements to ensure timely replenishment of stock is a considerable challenge (Chopra & Meindl, 2016). Shelf life and perishability are critical factors, particularly for products in the food and beverage category. Many FMCG products have limited shelf lives, and managing inventory to minimize waste while ensuring product freshness is crucial (Nahmias, 2011). High inventory holding costs pose another challenge. Maintaining high inventory levels can lead to increased holding costs, including warehousing, insurance, and obsolescence costs. Therefore, balancing inventory levels to minimize costs while meeting demand is essential (Arnold, Chapman, & Clive, 2008). The technological integration required for advanced inventory management systems and technologies, such as RFID and ERP systems, demands significant investment and can be challenging for many FMCG companies (Gunasekaran & Ngai, 2004). Global supply chain disruptions such as natural disasters, political instability, and pandemics can disrupt global supply chains, making inventory management even more challenging (Ivanov & Dolgui, 2020). Regulatory compliance adds another layer of complexity. FMCG companies must comply with various regulations related to product safety, labeling, and environmental impact, which can affect inventory management practices (Harland et al., 2005). Modern consumers expectations for high product availability, fast delivery, and a seamless shopping experience add pressure on FMCG companies to optimize their inventory management (Ailawadi, Neslin, & Gedenk, 2001). The growing awareness and demand for sustainable products necessitate changes in inventory management practices, such as reducing waste and optimizing the supply chain for sustainability (Seuring & Müller, 2008). The integration of omni-channel strategies is a significant challenge in managing inventory across multiple sales channels (online and offline) to ensure a consistent customer experience (Brynjolfsson, Hu, & Rahman, 2013).

Descriptive Analysis

Year-wise patterns in research show that publications on the fintech revolution began to emerge predominantly in 2015 and have since exhibited a relatively steady and somewhat incremental growth. It is evident that the quantity of article produced annually is not substantial enough, suggesting that the realm of fintech revolution remains inadequately explored.

Year Wise Distribution



Top 10 Authors and Citations

Authors	Citations
P Bingi, MK Sharma, JK Godla	2281
MF Steger, BJ Dik, RD Duffy	2160
TB Jørgensen, B Bozeman	1619
FR McDougall, PR White, M Franke, P Hindle	1467
J Brilha	1246
WE McCarthy	1195
M Li, Q Zhang, J Kurokawa, JH Woo…	1147
BZ Posner, JM Kouzes	1065
JW Varni, TM Burwinkle, JR Jacobs…	789
J Hyyppä, H Hyyppä, D Leckie, F Gougeon…	764

P Bingi, MK Sharma and JK Godla are distinguished as the foremost contributors within the realm of financial services, boasting 2281 citations. In a similar MF Steger, BJ Dik and RD Duffy have garnered 2160 citations, establishing them as the second-highest contributors in the domain of fast-moving consumer goods industry

Top 10 Publishers and Citations

Publishers	Citations
Inf. Syst. Manag.	2281
Journal of career Assessment	2160
Administration &society	1619
International Journal of Production …	1405
Management Science	1323
Geoheritage	1246
Accounting review	1195
Atmospheric …	1147
Educational and psychological …	1065
Diabetes …	789

The tabulated data illustrates the foremost ten publishers who have made significant contributions in the field of fast-moving consumer goods industry over a decade. The leading publisher in this realm is Inf. Syst. Manag. having 2281 publications cited, followed closely by Journal of career Assessment with 2160 publications cited.

Research Methodology

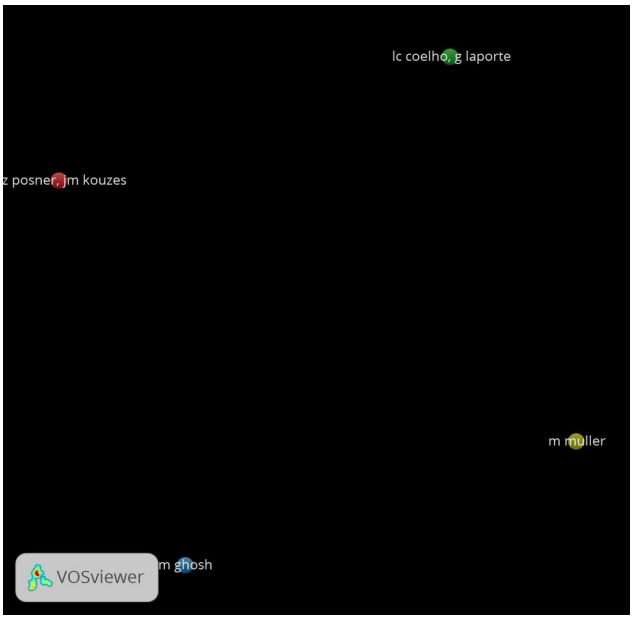
Numerous methodologies for executing a literature review involve systematic literature review (SLR), meta-analysis, bibliometric study, and content analysis. The present investigation employs the SLR methodology to ascertain, categorize, and present the pertinent scholarly articles.

Bibliometric analysis

Bibliometric analysis is primarily conducted to identify the highly globally cited, locally cited, and reputable research papers within a specific research domain. Various approaches are employed to identify local citations and PageRank. Local citation can be attained through citation or co-citation analysis using VOS viewer, where VOS stands for the visualization of similarities. In this study, the co-citation analysis option was selected to generate local citations. The rationale for opting for VOS viewer over other available software is derived from the description of VOS viewer provided by van Eck and Waltman (2010) stating that "VOS viewer can present a map in diverse manners, each highlighting a distinct aspect of the map. It offers features such as zooming, scrolling, and searching, thereby facilitating a thorough examination of a map. The visualization capabilities of VOS viewer are particularly beneficial for maps with a considerable number of items (e.g., at least 100 items).

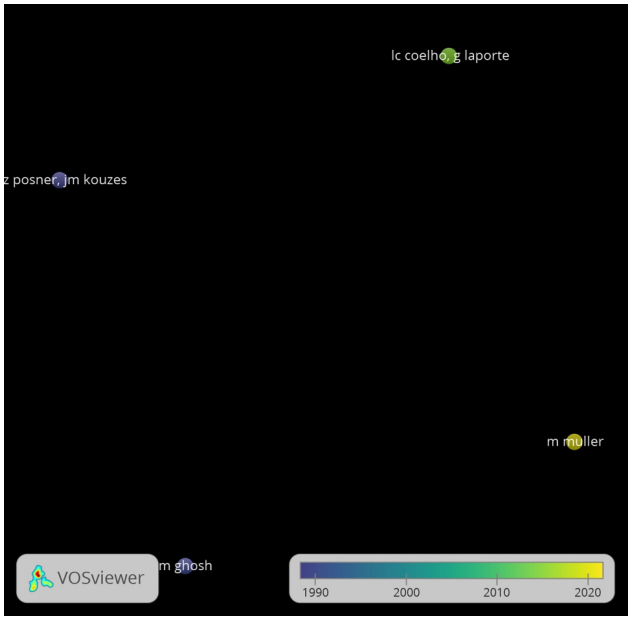
Most software programs utilized for bibliometric mapping fail to present such maps satisfactorily.

Network Visualization



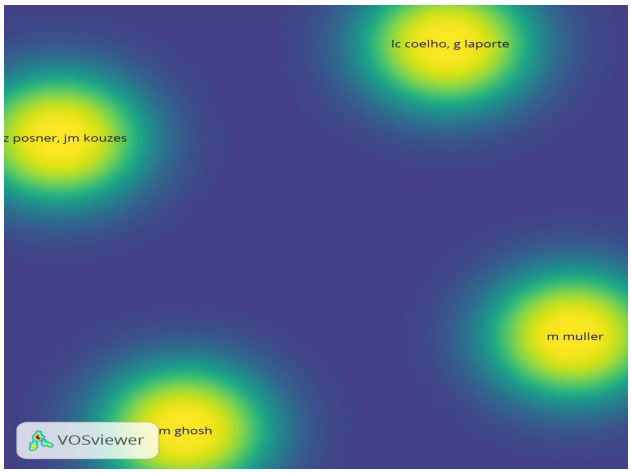
Network visualization is a technique that graphically represents complex relationships and interactions within a system using nodes (entities) and edges (connections). It simplifies the identification of key players, influential connections, and hidden patterns, enhancing data interpretation and decision-making. This method is valuable in various contexts, such as social networks and communication systems, by making intricate data structures more accessible and understandable.

Overlay Visualization



Overlay visualization involves layering multiple datasets or visual elements on a single graph or chart to compare and contrast data, highlight relationships, and identify patterns. This technique enhances data interpretation and supports more informed analysis and decision-making by providing a comprehensive, unified view.

Density Visualization

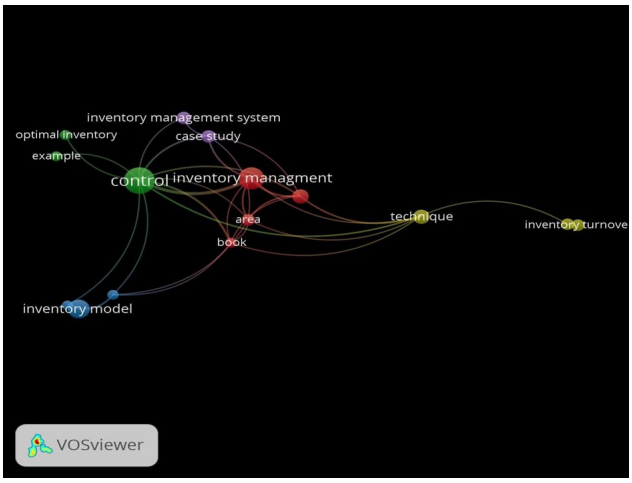


Density visualization is a technique used to represent the concentration of data points within a particular area. It helps identify regions of high and low data density, revealing patterns, trends, and anomalies that might be hidden in raw data. This method is commonly used in geographic mapping and scatter plots to enhance data interpretation and support better decision-making.

Meta Analysis

Meta-analysis in VOS viewer involves systematically combining results from multiple studies to identify patterns, relationships, and overall trends in a specific research area. VOS viewer helps visualize these relationships through network maps, making it easier to interpret complex data.

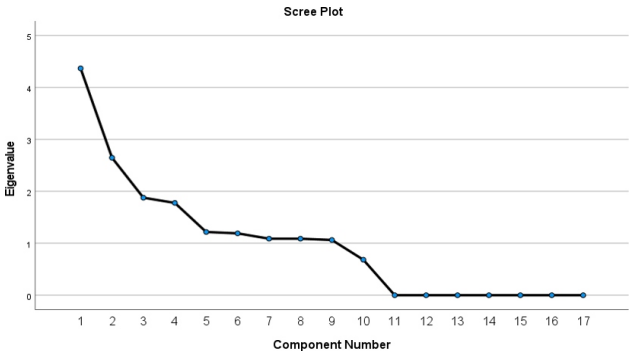
Term Id	Term	Occurrences
1	accuracy	23
2	article	21
3	backorder	36
4	book	4
5	study	6
6	cost	7
7	control	7
8	types	6
9	inventory management system	47
10	inventory management	13
11	inventory model	4
12	inventory turnover	15
13	optimal inventory	5
14	profitability	10
15	technique	25
16	technology	5



The image you provided appears to be a network graph, a visual representation of relationships or connections between various nodes. In this type of graph, nodes typically represent individual entities or data points, while edges (lines) indicate the relationships or connections between them. The color-coded nodes and edges help differentiate between different types of entities or relationships, making it easier to identify clusters and patterns within the data. The layout of nodes in a network graph can also offer insights into the roles of different entities within the network. Nodes that are centrally located and have many connections may signify key entities with high influence or importance, while nodes on the periphery with fewer connections may represent less influential entities. This visualization technique is commonly used in various fields such as social network analysis, bioinformatics, and strategic planning to analyze complex systems, identify significant interactions, and uncover underlying patterns or structures within the data.

Content Analysis

Papers within clusters are categorized according to the similarity of their research themes, thus demonstrating that clustering is a potent instrument for unveiling diverse facets of topics present in current literature. The approach adopted involved assigning varying degrees of importance to citations based on their strength and weight. Diverse clusters are distinguished by a variety of colors, while the magnitude of the circle corresponds to the quantity of citations garnered by a particular article.



Scree Plot

A scree plot is a graphical aid commonly used in statistical analysis, particularly in factor analysis, to assist in deciding how many factors or components should be retained for further study. This plot takes the eigenvalues of factors or components, arranged in descending order, and plots them against the number of factors or components considered. By examining the scree plot, researchers can identify the point where eigenvalues flatten out, indicating the optimal number of factors to retain based on the variance they explain.

Total Variance Explained

Initial Eigenvalues				Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.015	33.432	33.432	5.015	33.432	33.432	3.463	23.087	23.087
2	3.408	22.720	56.153	3.408	22.720	56.153	3.419	22.791	45.878
3	3.131	20.871	77.024	3.131	20.871	77.024	3.222	21.481	67.360
4	1.931	12.874	89.897	1.931	12.874	89.897	2.524	16.826	84.186
5	1.515	10.103	100.000	1.515	10.103	100.000	2.372	15.814	100.000
6	1.806E-15	1.204E-14	100.000						
7	3.679E-16	2.453E-15	100.000						
8	2.380E-16	1.586E-15	100.000						
9	1.422E-16	9.480E-16	100.000						
10	8.818E-17	5.879E-16	100.000						
11	-5.310E-17	-3.540E-16	100.000						
12	-1.429E-16	-9.527E-16	100.000						
13	-2.361E-16	-1.574E-15	100.000						
14	-2.699E-16	-1.799E-15	100.000						
15	-5.437E-16	-3.625E-15	100.000						

Extraction Method: Principal Component Analysis.

Component Matrix[a]

Component	1	2	3	4	5
Accuracy	-.963	.108	-.044	.216	.109
Article	.537	.201	.748	-.199	-.270
Backorder	.822	-.286	-.406	.237	.145
Book	.784	.391	-.043	-.386	-.286
Case Study	.507	-.009	.668	.244	.487
Cost	-.268	.271	.162	.902	-.118
Control	.329	-.471	-.795	.090	.171
Example	.744	.455	-.373	.271	.166
Inventory Management System	.344	.877	-.179	-.225	.171
Inventory Management	-.442	-.642	-.148	-.169	-.586
Inventory Model	-.424	.707	-.211	.506	-.142
Inventory Turnover	-.517	.521	.639	-.231	-.002
Optimal Inventory	-.443	-.290	.200	-.307	.765
Profitability	-.188	.717	-.573	-.349	-.026
Technique	.725	-.263	.532	.285	-.203

Rotated Component Matrix[a]

Component	1	2	3	4	5
Accuracy					.527
Article	.626				
Backorder	.316				
Book				.734	
Case Study	.886				
Cost		·			.980
Control					
Example			.768		
Inventory Management System			.897		
Inventory Management					
Inventory Model					.811
Inventory Turnover		.978			
Optimal Inventory		.180			
Profitability			.471		
Technique	.891				

Term	Eigenvalues
accuracy	More than 1
article	
backorder	
book	
study	
cost	
control	
types	
inventory management system	Less than 1
inventory management	
inventory model	
inventory turnover	
optimal inventory	
profitability	
techniques	
technology	
systematic literature review	
technology	

Total Variance Explained

The Rotated Component Matrix in Principal Component Analysis (PCA) is a crucial outcome that simplifies and interprets complex datasets. PCA is a statistical technique used to streamline data by reducing the number of variables while retaining essential variation. This involves transforming original variables into a new set of linearly uncorrelated components. The Rotated Component Matrix presents these components in a rotated form after applying an orthogonal transformation, which enhances interpretability. Each component in the matrix represents a linear combination of the original variables, helping to understand which variables contribute most significantly to the variance of each component. Therefore, the Rotated Component Matrix not only simplifies the dataset but also aids in insightful analysis by highlighting the underlying structure and relationships among variables in a more manageable format.

Principal Component Analysis (PCA) is essential for simplifying datasets while preserving important information. It transforms original variables into uncorrelated variables called principal components, ordered by the variance they explain. To aid interpretation, PCA often uses rotation methods like Varimax, which maximizes variance of squared loadings within each principal component. Kaiser Normalization adjusts these loadings to reflect total variance in the data, ensuring accuracy. Varimax rotation convergence, typically after 9 iterations, optimizes components for clarity. Iteration duration varies with data complexity and rotation method, ensuring effective transformation of complex datasets into manageable components that provide insight

Clustering
Cluster 1: cost, control, inventory management
Cluster 2: type, technique, profitability
Cluster 3: accuracy, study
Cluster 4: inventory model, inventory turnover
Cluster 5: optimal inventory, inventory management system

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