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ADOPTION OF INDUSTRY 4.0 IN FMCG SECTOR: IMPLICATIONS OF SUPPLY CHAIN SUSTAINABILITY

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ABSTRACT

The advent of Industry 4.0 has introduced transformative digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and automation, significantly reshaping the Fast-Moving Consumer Goods (FMCG) sector. This study explores the adoption of Industry 4.0 in the FMCG industry and its implications for supply chain sustainability. Using a structured questionnaire, the research captures perceptions related to awareness, understanding, and the environmental impact of these technologies. The findings reveal a high level of familiarity with Industry 4.0 concepts among participants, along with a strong belief in its role in improving supply chain efficiency, reducing waste and pollution, and promoting green logistics and packaging. Respondents recognize that automation and data-driven processes contribute to sustainable operations and highlight the necessity for companies to embrace eco-friendly practices not only as a responsibility but as a strategy to enhance brand image and consumer support. Furthermore, the study underscores the importance of educating students and future professionals on sustainable technologies, integrating these topics into academic curricula, and fostering conscious consumption behaviours. The insights affirm that Industry 4.0 serves as a catalyst for sustainable transformation in the FMCG sector, driven by technological advancement, environmental responsibility, and informed stakeholders.

KEYWORDS: *Industry 4.0, FMCG, Supply Chain Sustainability, Digital Transformation, Smart Logistics.*

INTRODUCTION

The Fourth Industrial Revolution, commonly referred to as Industry 4.0, represents a paradigm shift in the way industries operate by integrating advanced digital technologies into traditional manufacturing and supply chain systems. These technologies—including the Internet of Things (IoT), Artificial Intelligence (AI), robotics, cloud computing, and big data analytics—are redefining efficiency, productivity, and decision-making across various sectors. Among the most impacted is the Fast-Moving Consumer Goods (FMCG) sector, a highly dynamic and competitive industry characterized by rapid product turnover, extensive supply chains, and high consumer demand. The FMCG sector relies heavily on operational efficiency, responsive supply chains, and adaptability to market trends, making it a prime candidate for the integration of Industry 4.0 technologies.

Concurrently, growing global concerns about climate change, resource depletion, and waste management have placed sustainability at the forefront of business strategy. Sustainable supply chains seek to minimize environmental impact, ensure ethical sourcing, and promote economic viability throughout the product lifecycle. In the context of FMCG, sustainability is particularly critical due to the sector's large-scale manufacturing, packaging, and distribution processes, which can significantly impact the environment. The fusion of Industry 4.0 technologies with sustainability goals has opened new avenues for creating environmentally responsible, data-driven, and agile supply chains. By harnessing automation, sensor-based monitoring, and predictive analytics, companies can reduce waste, optimize energy use, and foster green logistics practices.

This research aims to examine the level of awareness, understanding, and perception surrounding the adoption of Industry 4.0 in the FMCG sector and its implications for sustainable supply chain management. The study investigates how digital innovations contribute to green supply chain practices, influence consumer and corporate behaviour, and shape the mindset of current and future professionals. The use of a comprehensive questionnaire serves to capture diverse insights from respondents on topics such as the role of automation in reducing pollution, the importance of green logistics, and the potential for technology to drive eco-friendly change. These insights help assess readiness levels and identify gaps in awareness or education that may hinder the full-scale adoption of sustainable Industry 4.0 practices.

Preliminary survey responses suggest a generally high level of familiarity with the concepts of Industry 4.0 and sustainable supply chains. Participants understand the application of technologies like AI, IoT, and automation in the FMCG sector and acknowledge their role in transforming traditional operations. Moreover, respondents demonstrate awareness of environmental concerns such as waste generation, energy inefficiency, and carbon emissions in supply chains. This suggests a growing recognition of the potential for Industry 4.0 to mitigate these issues. Many also expressed an understanding of specific green supply chain practices such as eco-friendly packaging, optimized logistics, and recycling, reflecting an

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encouraging trend in environmental consciousness among stakeholders.

A significant insight from the survey is the emphasis on the role of education in promoting sustainable industry practices. Respondents widely agreed that students and future professionals should be trained in both Industry 4.0 technologies and sustainability principles. This reflects a belief in the long-term benefits of embedding these topics into academic curricula, ensuring that the next generation of managers is equipped with the knowledge and tools to implement responsible business practices. Additionally, the role of youth as consumers and influencers in encouraging companies to adopt green technologies was recognized, highlighting the growing power of informed, conscious consumption in driving corporate sustainability agendas.

The study also reveals a strong sentiment that FMCG companies have a moral and strategic responsibility to implement sustainable supply chain practices. Many respondents supported the idea that green logistics and eco-friendly packaging should be mandatory rather than optional. They also believed that companies practicing sustainability are more likely to enjoy brand loyalty, competitive advantage, and positive public perception. With consumers increasingly favouring brands that align with environmental values, businesses must adapt to meet these expectations. The integration of Industry 4.0 enables firms to balance profitability with environmental stewardship, thereby fostering resilience and long-term viability in a market that is becoming more sustainability-focused.

This paper, therefore, seeks to explore how the convergence of Industry 4.0 and sustainable practices can revolutionize supply chains in the FMCG sector. Specifically, it examines stakeholders' awareness, evaluates perceived benefits, and identifies challenges to adoption. The research is structured as follows: a review of existing literature on Industry 4.0 and sustainability in supply chains; a detailed analysis of survey data reflecting stakeholder perceptions; discussion of implications for industry and education; and finally, conclusions with recommendations for future action. By capturing real-world perspectives, the study aims to contribute to the academic and practical understanding of how digital transformation can be harnessed to build greener, more sustainable supply chains in the FMCG landscape.

LITERATURE REVIEW

1. Md Shihab Shakur, Maishat Lubaba, Binoy Debnath, A.B.M. Mainul Bari, M. Azizur Rahman (2024) investigates the integration of Industry 4.0 (I4.0) technologies within the FMCG sector of emerging economies, focusing on their impact on supply chain resilience. The authors identify nine major challenges impeding adoption, including the need for significant investment, technological incompatibility, and fragmented value chains. Employing the Bayesian Best Worst Method (BWM), the study systematically prioritizes these challenges and offers strategic insights into overcoming them. Technologies such as IoT, big data analytics, AI, blockchain, and digital twins are highlighted for their potential to enhance visibility, agility, and sustainability in supply chains. The paper emphasizes that despite the transformative potential of I 4.0, full-scale adoption remains limited in many FMCG firms due to organizational inertia and infrastructural gaps. The research offers practical guidance for decision-makers to formulate targeted strategies, advocating for digital readiness, workforce training, and improved infrastructural support. It ultimately positions I4.0 adoption as a critical enabler of a resilient, efficient, and sustainable FMCG supply chain ecosystem.
2. Mohammad Fallah, Hamed Nozari(2020) examines the cyber risks associated with IoT-based supply chains in the FMCG industry. As the Internet of Things becomes integral to modern supply chain operations, especially for real-time monitoring and automation, the authors explore its vulnerability to cyber threats. Using nonlinear mathematical modeling, they identify and rank cyber risks, with privacy concerns in interactions between suppliers and customers emerging as the most critical. The study stresses that while IoT offers significant operational efficiencies and visibility benefits, its open network structure exposes FMCG firms to data breaches, hacking, and privacy violations. The findings suggest that businesses must invest in robust cybersecurity frameworks and proactive risk mitigation strategies to protect the digital infrastructure underlying their smart supply chains. The paper provides a strong foundation for integrating security planning into IoT adoption strategies, highlighting the importance of balancing innovation with risk management in the journey toward Industry 4.0 in FMCG contexts.
3. Hamed Nozari, Mohammad Fallah, Hamed Kazemipoor, Seyed Esmaeil Najafi(2021) presents a comprehensive analytical framework for building a sustainable smart supply chain in the FMCG industry using IoT-generated big data. The authors explore how the integration of IoT and big data analytics can transform supply chain decision-making, enhance operational efficiency, and foster sustainability. The proposed model highlights how FMCG companies can use real-time data from connected devices to improve demand forecasting, inventory control, and resource optimization. By emphasizing expert validation and case-specific analysis, the framework shows how intelligent data systems can drive performance improvements and adaptability. While acknowledging challenges such as data overload and cybersecurity, the paper underlines the transformative potential of a data-driven supply chain. It provides a roadmap for firms looking to digitize and modernize their supply chains, making it especially relevant for decision-makers seeking to align digital initiatives with strategic business goals in the context of Industry 4.0.
4. Sara Viviana Gallo Orjuela, Anais Ortega Camacho(2020) addresses the gap between technological implementation and human readiness in the digital transformation of FMCG manufacturing. Focusing on Beverages, a multinational beverage company, the authors propose a strategic framework for classifying bottling plants based on digital maturity and operational performance. The study

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combines ERP data analysis and surveys to cluster plants into groups and tailor digital transformation strategies accordingly. Key findings reveal that a one-size-fits-all approach to technology adoption often fails due to differences in digital readiness across facilities. Therefore, the authors recommend customized strategies that consider employee training, change management, and operational context. By aligning technological initiatives with organizational capabilities, the study offers practical insights into developing scalable and sustainable digital transformation roadmaps. This research is particularly valuable for supply chain leaders seeking to implement Industry 4.0 in a phased, human-cantered, and performance-driven manner within the FMCG sector.

5. Abdel-Basset et al. (2018) proposed a comprehensive framework for building smart, secure, and sustainable supply chains using Industry 4.0 technologies such as the Internet of Things (IoT), cloud computing, and AI. The study highlights how these technologies can enhance operational transparency, real-time decision-making, and predictive analytics within FMCG supply chains. The authors assert that implementing IoT-based sensors improves energy efficiency and reduces material wastage, thus supporting environmental sustainability. Moreover, the integration of smart devices facilitates data-driven decisions that minimize inventory surplus and carbon emissions. However, they also note the necessity of overcoming cybersecurity challenges and infrastructural gaps to ensure successful implementation. The paper emphasizes the importance of aligning digital strategies with sustainability goals, especially in industries where rapid product turnover and short shelf-life demand efficiency. The framework serves as a valuable roadmap for FMCG firms striving to transition into Industry 4.0 while maintaining a commitment to ecological responsibility. This study lays the groundwork for assessing digital maturity and its correlation with sustainability performance.
6. Bag et al. (2020) investigate the impact of Industry 4.0 technologies—particularly Big Data Analytics and IoT—on green supply chain practices in the FMCG sector. The study utilizes empirical data from Indian manufacturing firms to reveal a positive correlation between digital adoption and environmental performance. Big Data enables granular visibility across the value chain, facilitating waste reduction, energy optimization, and better demand forecasting. The authors also argue that real-time monitoring, enabled through IoT, supports proactive decision-making and enhances overall supply chain responsiveness. In FMCG companies, where speed and volume are critical, these capabilities are essential for minimizing overproduction and reducing environmental burden. Furthermore, the paper suggests that digital transformation influences supplier coordination and reverse logistics, two critical factors in sustainable supply chain management. The study concludes that organizations that integrate Industry 4.0 tools into their operations not only gain a competitive edge but also fulfill corporate sustainability goals. However, a significant challenge lies in the high initial investment and lack of skilled workforce for seamless integration.
7. Kamble et al. (2018) focus on the transformative role of Industry 4.0 in achieving sustainable supply chains in emerging economies, with a special focus on the FMCG industry in India. Using a structured survey of manufacturing professionals, the study identifies technologies such as automation, cyber-physical systems, and cloud integration as key enablers of green and lean supply chains. The findings reveal that the use of real-time data enhances supply chain traceability, optimizes logistics, and minimizes environmental waste. This is particularly relevant in the FMCG sector, where rapid product cycles can lead to inefficiencies. The authors argue that while the potential benefits are immense, successful implementation hinges on organizational readiness and change management practices. The paper also highlights the importance of collaboration across the supply chain network to ensure coherent sustainability outcomes. Kamble et al. recommend that Indian FMCG companies invest in digital talent and collaborative innovation ecosystems to extract full value from Industry 4.0 initiatives. The study serves as a critical reference for developing digital and sustainability integration strategies in the sector.
8. Sony and Naik (2019) present a conceptual model outlining how Industry 4.0 technologies influence sustainability across supply chains. The authors argue that technologies such as AI, IoT, and advanced robotics improve resource utilization and reduce human error, leading to more sustainable production cycles. In the context of the FMCG sector, which is characterized by high product volumes and short delivery timelines, these technologies offer significant benefits in reducing waste and emissions. The paper also emphasizes the role of cyber-physical systems and smart factories in improving operational efficiency. The authors identify environmental, economic, and social sustainability as core pillars enhanced by digital transformation. However, the research warns of potential risks including job displacement and unequal access to technology, especially in developing countries. This dual perspective—of opportunities and limitations—adds depth to the discourse on Industry 4.0 and sustainability. The paper concludes that strategic alignment of digital initiatives with sustainability frameworks is essential for the long-term success of FMCG firms aiming for responsible growth.
9. Manavalan and Jayakrishna (2019) explore how Industry 4.0 technologies contribute to supply chain resilience and sustainability. Through a comprehensive review of recent studies, the authors construct a theoretical framework that links technological enablers such as autonomous systems, cloud-based logistics, and blockchain with sustainable practices like waste minimization, circular economy, and green sourcing. In the FMCG context, where speed, scalability, and flexibility are essential, these technologies offer mechanisms to ensure environmental compliance and consumer trust. The paper also discusses the role of simulation and digital twins in optimizing production layouts and energy consumption. A key insight from the

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study is that sustainability should be embedded in the digital transformation roadmap rather than treated as an auxiliary goal. The authors advocate for regulatory incentives and industry collaborations to drive adoption. This research contributes valuable perspectives on the systemic integration of digital and sustainable strategies in FMCG supply chains and underlines the need for continuous capability development.

10. Kumar et al. (2021) conduct an empirical study on the role of Industry 4.0 adoption in enhancing sustainable supply chain practices in the Indian FMCG sector. The study employs structural equation modeling (SEM) to analyze data from supply chain professionals and finds that digitalization significantly influences key sustainability dimensions—namely, green procurement, eco-friendly packaging, and low-carbon logistics. The authors highlight that real-time visibility, enabled through cloud computing and sensors, allows companies to make environmentally responsible decisions in sourcing and inventory management. Furthermore, they find that employee training and organizational culture are mediators in the successful implementation of Industry 4.0. A novel contribution of this study is its focus on the human element in digital transformation—an area often overlooked. The research also points to policy gaps and infrastructure limitations that hinder broader adoption in the Indian context. It concludes by recommending government support and industry-wide knowledge-sharing platforms to promote sustainable digital adoption in FMCG supply chains.

RESEARCH GAP

- Most existing studies focus on Industry 4.0 in manufacturing or industrial sectors, with limited research specifically analysing its integration and impact within the FMCG supply chains.
- There is a research gap in understanding how aware students and young professionals are of Industry 4.0 and sustainable supply chain practices, despite their potential role as future decision-makers.
- Few studies capture stakeholder perceptions of how digital technologies contribute to reducing waste, emissions, and pollution in the FMCG sector specifically.
- The role of curriculum and education systems in promoting Industry 4.0 and sustainability literacy remains under-researched, particularly in relation to FMCG-specific skills.
- Research seldom focuses on how consumer perception and conscious consumption influence companies to adopt green supply chain technologies and practices in the FMCG industry.

OBJECTIVES

Primary Objective

- To evaluate the level of awareness and understanding of Industry 4.0 and sustainable supply chain practices among stakeholders in the FMCG sector.
- To analyze the perceived impact of Industry 4.0 technologies on environmental sustainability within FMCG supply chains.

Secondary Objectives

1. To assess the role of educational institutions in preparing students for sustainability-driven digital transformations in supply chains.
2. To explore consumer and youth perspectives on the adoption of green supply chain practices in the FMCG sector.
3. To identify the key barriers and enablers influencing the integration of Industry 4.0 for sustainable outcomes in FMCG supply chains.

RESEARCH METHODOLOGY

Null Hypothesis (H_0)

Stakeholders do not perceive Industry 4.0 technologies as having a significant positive impact on supply chain sustainability in the FMCG sector.

Alternative Hypothesis (H_1)

Stakeholders perceive Industry 4.0 technologies as having a significant positive impact on supply chain sustainability in the FMCG sector.

RESEARCH DESIGN

The research follows a descriptive and analytical design, focusing on understanding the perceived impact of Industry 4.0 technologies on supply chain sustainability in the FMCG sector. A quantitative method was employed using structured questionnaires that included Likert-scale items designed to explore:

- Awareness and understanding of Industry 4.0
- Beliefs about the role of digital technologies (IoT, AI, automation) in promoting sustainability
- Perceived effects of Industry 4.0 on waste reduction, energy efficiency, and eco-friendly operations
- Opinions on green logistics and sustainable packaging
- Views on the responsibility of FMCG companies in adopting Industry 4.0 for environmental benefits

This design allowed for a systematic and objective approach to data collection and analysis, focusing on stakeholder perceptions related to sustainability transformations driven by digital innovation.

Quantitative data was analysed using Statistical Package for the Social Sciences (SPSS) and Microsoft Excel. Analytical techniques included:

- Descriptive statistics (mean, frequency, standard deviation)
- Hypothesis testing using chi-square tests and t-tests to validate the significance of relationships

The study adopted a non-probability convenience sampling method, utilizing online self-administered questionnaires. Respondents were selected based on their availability, interest in the topic, and willingness to participate. The sample included individuals from different educational and professional backgrounds, including students, early-career professionals, and sustainability-aware consumers. This method enabled

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targeted outreach to participants who are likely to have opinions or awareness about Industry 4.0 and green supply chains in the FMCG sector.

Sample Size

Responses were collected from approximately 548 participants, including a balanced mix of students, early-career professionals, and general consumers. The sample provided a rich cross-section of demographics including education level, and professional background. This helped support the research goals with relevant and targeted stakeholder perspectives on Industry 4.0 and sustainable supply chain practices in the FMCG sector.

Data Collection

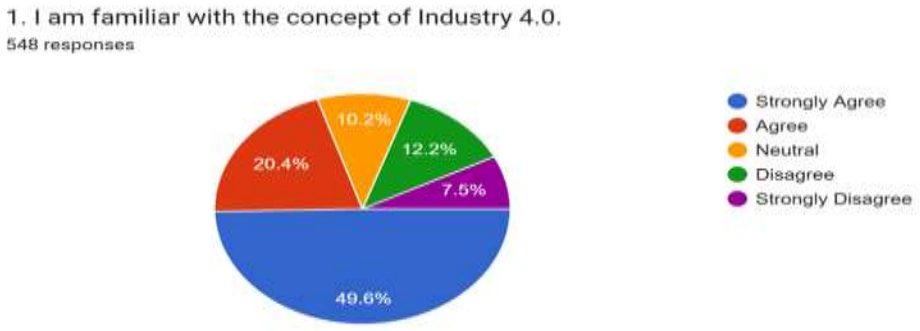
Primary data was collected via a digital survey, shared through email and social media platforms. The questionnaire consisted of 20 Likert-scale statements aligned with research constructs such as Industry 4.0 awareness, sustainability perceptions, green practices, and education influence. Respondents rated their agreement on a 5-point scale (from Strongly Disagree to Strongly Agree).

Statistical Tools Used

The study used descriptive statistics to summarize key data such as age distribution, content preferences, and engagement frequency. Likert scale results were analyzed to gauge sentiment on content type and brand responsiveness. Additionally, analysis was employed to explore relationships between variables like content frequency and likelihood to engage.

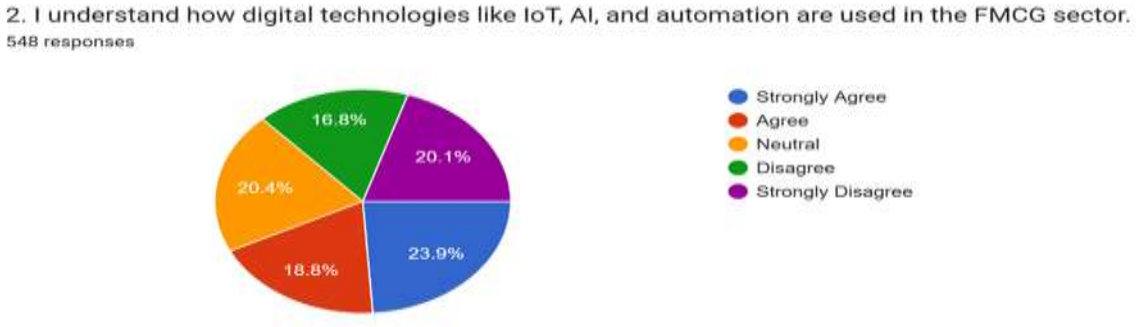
ANALYSIS AND INTERPRETATION

1. I am familiar with the concept of Industry 4.0.



Nearly half of the respondents (49.6%) feel very confident (Strongly Agree) about their familiarity with Industry 4.0., about one-fifth of the respondents (20.4%) are somewhat (Agree) familiar with the concept, around one-eighth of the respondents (12.2%) are undecided or moderately familiar (Neutral), approximately one-tenth of the respondents (10.2%) are not familiar with the concept (Disagree) and a smaller portion (7.5%) feels completely unfamiliar (Strongly Disagree) with Industry 4.0. Overall, the majority (69.4%) of respondents either agree or strongly agree that they are familiar with Industry 4.0, indicating a generally high level of awareness.

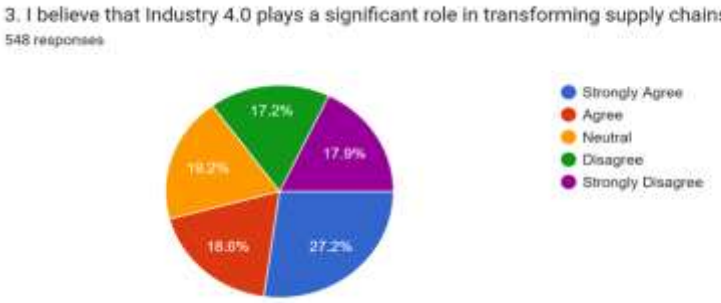
2. I understand how digital technologies like IoT, AI, and automation are used in the FMCG sector.



Nearly one-quarter of the respondents (23.9%) feel very confident (Strongly Agree) about their understanding of digital technologies in the FMCG sector, about one-fifth of the respondents (20.4%) are somewhat (Agree) familiar with the concept, around one-fifth of the respondents (20.1%) are undecided or moderately familiar (Neutral), approximately one-sixth of the respondents (18.8%) are not familiar with the concept (Disagree), and a smaller portion (16.8%) feels completely unfamiliar (Strongly Disagree) with the use of these technologies. Overall, a notable portion (44.3%) of respondents either agree or strongly agree that they understand the use of digital technologies in the FMCG sector, indicating a moderate level of awareness.

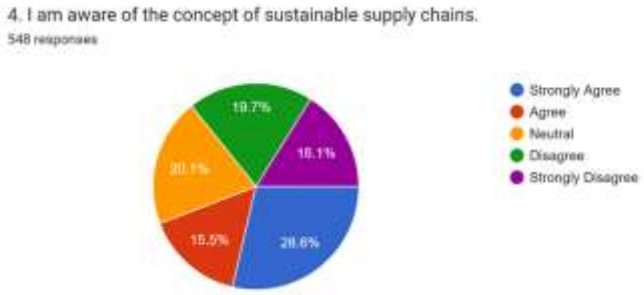
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3. I believe that Industry 4.0 plays a significant role in transforming supply chains.



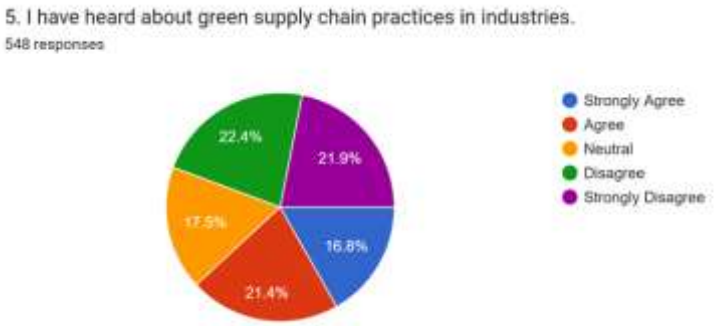
Over one-quarter of the respondents (27.2%) feel very confident (Strongly Agree) that Industry 4.0 plays a significant role in transforming supply chains, about one-fifth of the respondents (19.2%) somewhat (Agree) believe in its significance, around one-sixth of the respondents (17.9%) are undecided or moderately convinced (Neutral), approximately one-sixth of the respondents (18.6%) do not believe in its significance (Disagree), and a smaller portion (17.2%) strongly disagrees with the statement (Strongly Disagree). Overall, nearly half (46.4%) of respondents either agree or strongly agree that Industry 4.0 significantly transforms supply chains, indicating a balanced perspective with moderate support.

4. I am aware of the concept of sustainable supply chains.



Over one-quarter of the respondents (28.6%) feel very confident (Strongly Agree) about their awareness of sustainable supply chains, about one-fifth of the respondents (20.1%) are somewhat (Agree) aware of the concept, around one-fifth of the respondents (19.7%) are undecided or moderately aware (Neutral), approximately one-sixth of the respondents (15.5%) are not aware of the concept (Disagree), and a smaller portion (16.1%) feels completely unaware (Strongly Disagree) of sustainable supply chains. Overall, nearly half (48.7%) of respondents either agree or strongly agree that they are aware of sustainable supply chains, indicating a moderate level of awareness.

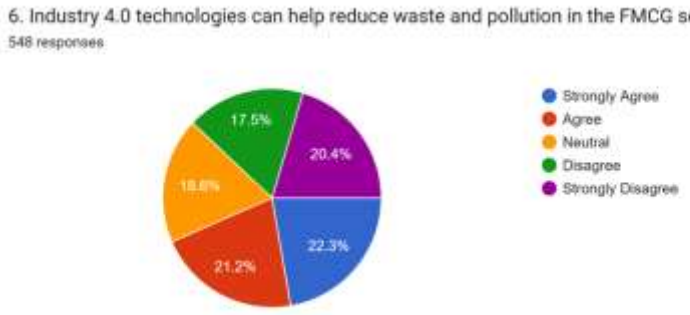
5. I have heard about green supply chain practices in industries.



Over one-fifth of the respondents (22.4%) feel very confident (Strongly Agree) that they have heard about green supply chain practices, about one-fifth of the respondents (21.4%) have somewhat (Agree) heard of the concept, around one-fifth of the respondents (22.2%) are undecided or moderately aware (Neutral), approximately one-sixth of the respondents (16.8%) have not heard of the concept (Disagree), and a smaller portion (17.2%) feels completely unaware (Strongly Disagree) of green supply chain practices. Overall, a notable portion (43.8%) of respondents either agree or strongly agree that they have heard of green supply chain practices, indicating a moderate level of awareness.

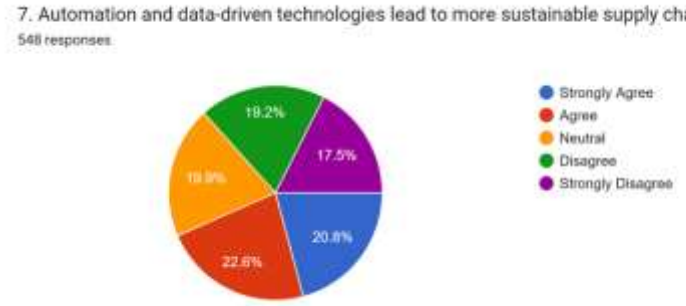
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6. Industry 4.0 technologies can help reduce waste and pollution in the FMCG sector.



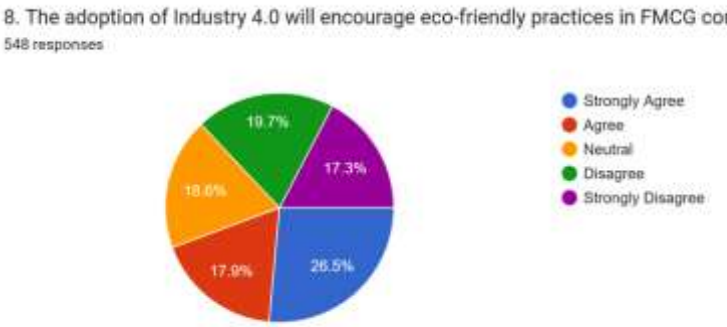
Over one-fifth of the respondents (22.3%) feel very confident (Strongly Agree) that Industry 4.0 technologies can reduce waste and pollution in the FMCG sector, about one-fifth of the respondents (21.2%) somewhat (Agree) believe in this potential, around one-fifth of the respondents (20.4%) are undecided or moderately convinced (Neutral), approximately one-sixth of the respondents (18.8%) do not believe in this potential (Disagree), and a smaller portion (17.5%) strongly disagrees with the statement (Strongly Disagree). Overall, a notable portion (43.5%) of respondents either agree or strongly agree that Industry 4.0 technologies can reduce waste and pollution, indicating a moderate level of optimism.

7. Automation and data-driven technologies lead to more sustainable supply chain operations.



About one-fifth of the respondents (20.8%) feel very confident (Strongly Agree) that automation and data-driven technologies lead to more sustainable supply chain operations, over one-fifth of the respondents (22%) somewhat (Agree) believe in this outcome, around one-fifth of the respondents (19.2%) are undecided or moderately convinced (Neutral), approximately one-fifth of the respondents (19.9%) do not believe in this outcome (Disagree), and a smaller portion (17.5%) strongly disagrees with the statement (Strongly Disagree). Overall, a notable portion (42.8%) of respondents either agree or strongly agree that automation and data-driven technologies enhance sustainability in supply chains, indicating a moderate level of support.

8. The adoption of Industry 4.0 will encourage eco-friendly practices in FMCG companies.

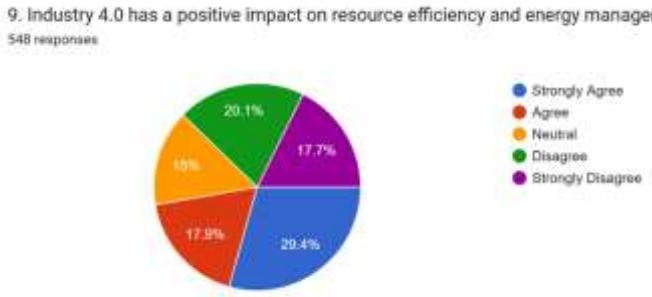


Over one-quarter of the respondents (26.5%) feel very confident (Strongly Agree) that Industry 4.0 adoption will encourage eco-friendly practices in FMCG companies, about one-sixth of the respondents (17.9%) somewhat (Agree) believe in this outcome, around one-fifth of the respondents (19.7%) are undecided or moderately convinced (Neutral), approximately one-sixth of the respondents (18.6%) do not believe in this outcome (Disagree), and a smaller portion

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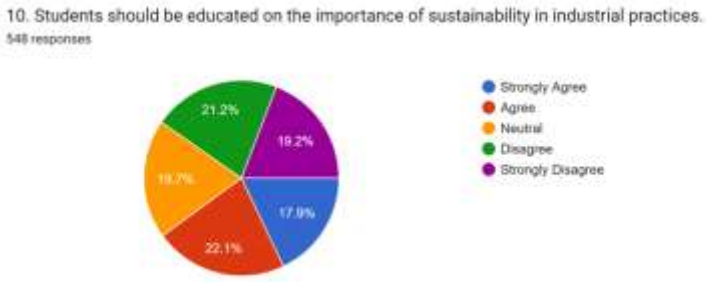
(17.3%) strongly disagrees with the statement (Strongly Disagree). Overall, a notable portion (44.4%) of respondents either agree or strongly agree that Industry 4.0 adoption will promote eco-friendly practices, indicating a moderate level of optimism.

9. Industry 4.0 has a positive impact on resource efficiency and energy management.



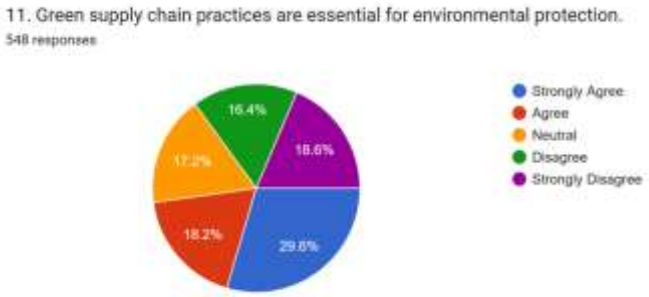
Over one-quarter of the respondents (29.4%) feel very confident (Strongly Agree) that Industry 4.0 has a positive impact on resource efficiency and energy management, about one-sixth of the respondents (17.9%) somewhat (Agree) believe in this impact, around one-fifth of the respondents (20.1%) are undecided or moderately convinced (Neutral), approximately one-sixth of the respondents (15%) do not believe in this impact (Disagree), and a smaller portion (17.7%) strongly disagrees with the statement (Strongly Disagree). Overall, nearly half (47.3%) of respondents either agree or strongly agree that Industry 4.0 positively impacts resource efficiency and energy management, indicating a moderate to high level of support.

10. Students should be educated on the importance of sustainability in industrial practices.



Over one-fifth of the respondents (22.1%) feel very confident (Strongly Agree) that students should be educated on the importance of sustainability in industrial practices, about one-fifth of the respondents (22.1%) somewhat (Agree) support this idea, around one-fifth of the respondents (21.2%) are undecided or moderately convinced (Neutral), approximately one-fifth of the respondents (17.9%) do not support this idea (Disagree), and a smaller portion (19.2%) strongly disagrees with the statement (Strongly Disagree). Overall, a notable portion (44.2%) of respondents either agree or strongly agree that students should be educated on sustainability in industrial practices, indicating a moderate level of support.

11. Green supply chain practices are essential for environmental protection.

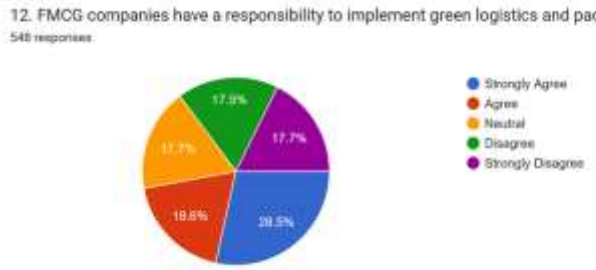


Over one-quarter of the respondents (29.6%) feel very confident (Strongly Agree) that green supply chain practices are essential for environmental protection, about one-sixth of the respondents (18.2%) somewhat (Agree) support this view, around one-sixth of the respondents (18.6%) are undecided or moderately convinced (Neutral), approximately one-sixth of the respondents (17.2%) do not support this view (Disagree), and a smaller portion (16.4%) strongly disagrees with the statement (Strongly Disagree). Overall, nearly half (47.8%) of respondents either agree or strongly agree that green supply

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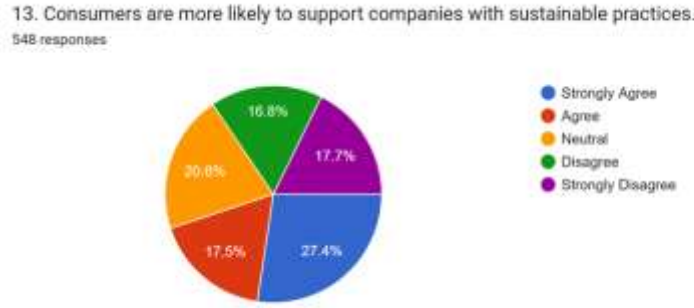
chain practices are essential for environmental protection, indicating a moderate to high level of support.

12. FMCG companies have a responsibility to implement green logistics and packaging.



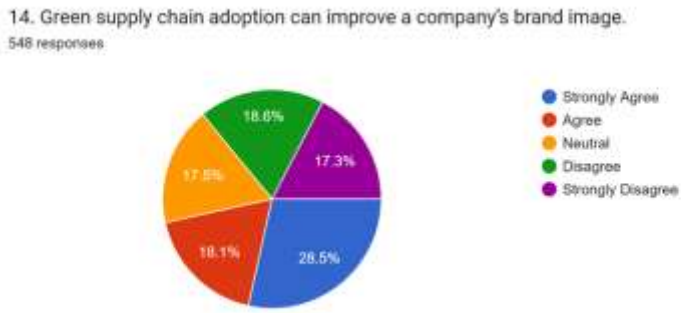
Over one-quarter of the respondents (28.5%) strongly believe (Strongly Agree) that FMCG companies have a responsibility to implement green logistics and packaging, around one-sixth of the respondents (18%) somewhat believe (Agree) in this responsibility, about one-sixth of the respondents (17.7%) are undecided or moderately convinced (Neutral), around one-sixth of the respondents (17.5%) do not believe (Disagree), and about one-sixth (17.7%) strongly do not believe (Strongly Disagree) in this responsibility. Overall, a significant portion (46.5%) of respondents either agree or strongly agree that FMCG companies have a responsibility to implement green logistics and packaging, indicating a generally positive perception.

13. Consumers are more likely to support companies with sustainable practices.



Over one-quarter of the respondents (27.4%) strongly believe (Strongly Agree) that consumers are more likely to support companies with sustainable practices, about one-sixth of the respondents (17.5%) somewhat believe (Agree) in this likelihood, one-fifth of the respondents (20.6%) are undecided or moderately convinced (Neutral), around one-sixth of the respondents (16.8%) do not believe (Disagree), and about one-sixth (17.7%) strongly do not believe (Strongly Disagree) in this likelihood. Overall, a notable portion (44.9%) of respondents either agree or strongly agree that consumers are more likely to support companies with sustainable practices, indicating a generally positive perception.

14. Green supply chain adoption can improve a company's brand image.Overly promotional content



Over one-quarter of the respondents (28.5%) strongly believe (Strongly Agree) that green supply chain adoption can improve a company's brand image, around one-sixth of the respondents (18%) somewhat believe (Agree) in this impact, about one-sixth of the respondents (17.5%) are undecided or moderately convinced (Neutral), around one-sixth of the respondents (18%) do not believe (Disagree), and about one-sixth (17.3%) strongly do not believe (Strongly Disagree) in this impact. Overall, a significant portion (46.5%) of respondents either agree or strongly agree that green supply chain adoption can improve a company's brand image, indicating a generally positive perception.

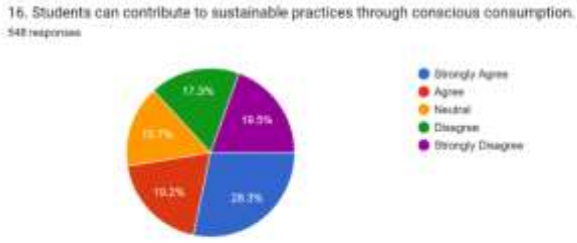
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15. Implementing green practices in supply chains should be mandatory.



About one-fifth of the respondents (21.2%) strongly believe (Strongly Agree) that implementing green practices in supply chains should be mandatory, one-fifth of the respondents (20.4%) somewhat believe (Agree) in this necessity, around one-fifth of the respondents (19.7%) are undecided or moderately convinced (Neutral), one-fifth of the respondents (20.6%) do not believe (Disagree), and about one-fifth (18.1%) strongly do not believe (Strongly Disagree) in this necessity. Overall, a notable portion (41.6%) of respondents either agree or strongly agree that implementing green practices in supply chains should be mandatory, indicating a moderate level of support.

16. Students can contribute to sustainable practices through conscious consumption.



Over one-quarter of the respondents (28.3%) strongly believe (Strongly Agree) that students can contribute to sustainable practices through conscious consumption, around one-fifth of the respondents (19.2%) somewhat believe (Agree) in this potential, about one-sixth of the respondents (15.7%) are undecided or moderately convinced (Neutral), around one-sixth of the respondents (17.3%) do not believe (Disagree), and about one-fifth (19.5%) strongly do not believe (Strongly Disagree) in this potential. Overall, a significant portion (47.5%) of respondents either agree or strongly agree that students can contribute to sustainable practices through conscious consumption, indicating a generally positive perception.

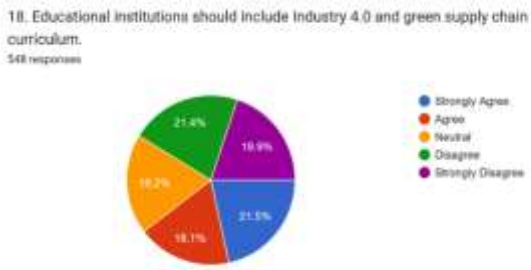
17. Future managers and professionals should be trained in Industry 4.0 and sustainability.



One-fifth of the respondents (20.4%) strongly believe (Strongly Agree) that future managers and professionals should be trained in Industry 4.0 and sustainability, around one-fifth of the respondents (19.5%) somewhat believe (Agree) in this need, over one-fifth of the respondents (22.3%) are undecided or moderately convinced (Neutral), about one-fifth of the respondents (18.2%) do not believe (Disagree), and around one-fifth (19.5%) strongly do not believe (Strongly Disagree) in this need. Overall, a notable portion (39.9%) of respondents either agree or strongly agree that future managers and professionals should be trained in Industry 4.0 and sustainability, indicating a moderate level of support.

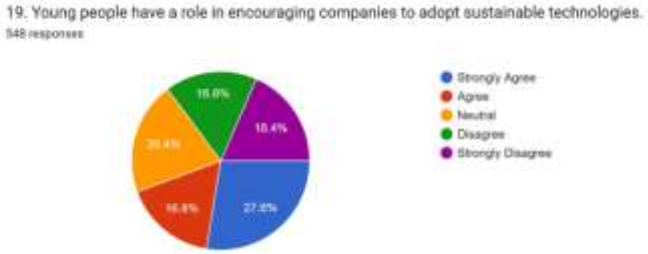
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18. Educational institutions should include Industry 4.0 and green supply chain topics in their curriculum.



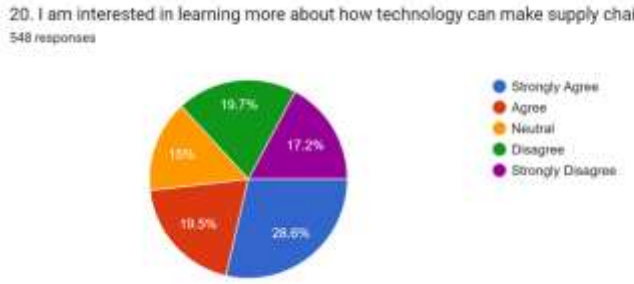
Over one-fifth of the respondents (21.5%) strongly believe (Strongly Agree) that educational institutions should include Industry 4.0 and green supply chain topics in their curriculum, around one-sixth of the respondents (18.1%) somewhat believe (Agree) in this need, about one-fifth of the respondents (19.2%) are undecided or moderately convinced (Neutral), over one-fifth of the respondents (21.4%) do not believe (Disagree), and around one-fifth (19.9%) strongly do not believe (Strongly Disagree) in this need. Overall, a notable portion (39.6%) of respondents either agree or strongly agree that educational institutions should include these topics in their curriculum, indicating a moderate level of support.

19. Young people have a role in encouraging companies to adopt sustainable technologies.



Over one-quarter of the respondents (27.6%) strongly believe (Strongly Agree) that young people have a role in encouraging companies to adopt sustainable technologies, around one-sixth of the respondents (16.8%) somewhat believe (Agree) in this role, one-fifth of the respondents (20.4%) are undecided or moderately convinced (Neutral), around one-sixth of the respondents (16.8%) do not believe (Disagree), and about one-fifth (18.4%) strongly do not believe (Strongly Disagree) in this role. Overall, a significant portion (44.4%) of respondents either agree or strongly agree that young people have a role in encouraging sustainable technology adoption, indicating a generally positive perception.

20. I am interested in learning more about how technology can make supply chains greener.



Over one-quarter of the respondents (28.6%) feel very interested (Strongly Agree) in learning more about how technology can make supply chains greener, around one-fifth of the respondents (19.5%) are somewhat interested (Agree) in this topic, about one-sixth of the respondents (15%) are undecided or moderately interested (Neutral), around one-fifth of the respondents (19.7%) are not interested (Disagree), and about one-sixth (17.2%) feel completely uninterested (Strongly Disagree) in this topic. Overall, a significant portion (48.1%) of respondents either agree or strongly agree that they are interested in learning more about how technology can make supply chains greener, indicating a generally high level of interest.

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Descriptive statistics

	Mean	Standard Deviation
1. I am familiar with the concept of Industry 4.0.	3.925182	1.326107196
11. Green supply chain practices are essential for environmental protection.	3.237226	1.490469776
20. I am interested in learning more about how technology can make supply chains greener.	3.228102	1.475260474
12. FMCG companies have a responsibility to implement green logistics and packaging.	3.226277	1.46995604
14. Green supply chain adoption can improve a companyâ€™s brand image.	3.217153	1.468224536
9. Industry 4.0 has a positive impact on resource efficiency and energy management.	3.211679	1.49064435
4. I am aware of the concept of sustainable supply chains.	3.209854	1.449242876
13. Consumers are more likely to support companies with sustainable practices.	3.20073	1.452426393
3. I believe that Industry 4.0 plays a significant role in transforming supply chains.	3.20073	1.457452454
16. Students can contribute to sustainable practices through conscious consumption.	3.193431	1.498015964
19. Young people have a role in encouraging companies to adopt sustainable technologies.	3.182482	1.464854458
8. The adoption of Industry 4.0 will encourage eco-friendly practices in FMCG companies.	3.164234	1.450725708
7. Automation and data-driven technologies lead to more sustainable supply chain operations.	3.100365	1.394347381
2. I understand how digital technologies like IoT, AI, and automation are used in the FMCG sector.	3.096715	1.452397682
6. Industry 4.0 technologies can help reduce waste and pollution in the FMCG sector.	3.072993	1.446852659
15. Implementing green practices in supply chains should be mandatory.	3.060219	1.407094049
17. Future managers and professionals should be trained in Industry 4.0 and sustainability.	3.021898	1.397135504
18. Educational institutions should include Industry 4.0 and green supply chain topics in their curriculum.	3	1.433472918
10. Students should be educated on the importance of sustainability in industrial practices.	2.983577	1.384724835
5. I have heard about green supply chain practices in industries.	2.886861	1.40577641

From the 548 survey responses analysed:

- The average mean score across all 20 items is approximately 3.17, indicating a moderate agreement or familiarity level among respondents regarding Industry 4.0, sustainability, and their interconnection in the FMCG sector.
- The average standard deviation is about 1.44, showing moderate variability in opinions, which may suggest a diverse set of awareness and experience levels among respondents.

Conclusion

- Respondents show moderate familiarity with Industry 4.0 technologies and sustainable supply chain practices in the FMCG sector.
- Statements related to consumer support for sustainability, training of future professionals, and educational inclusion of green practices received higher agreement, indicating strong support for educational and ethical shifts.
- Items addressing technical integration, such as the role of IoT and automation in reducing pollution, received slightly lower but still positive responses.
- This implies a need for greater awareness and training initiatives to fully realize the sustainability benefits of Industry 4.0.
- Overall, the findings suggest that while there is positive perception, actual adoption may depend on bridging the knowledge and application gap within industry and education.

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T-Test (Neutral Value = 3):

Question	T-Statistic	P-Value
1. I am familiar with the concept of Industry 4.0.	16.33199	3.94E-49
2. I understand how digital technologies like IoT, AI, and automation are used in the FMCG sector.	1.558835	0.119614
3. I believe that Industry 4.0 plays a significant role in transforming supply chains.	3.224096	0.001339
4. I am aware of the concept of sustainable supply chains.	3.38974	0.00075
5. I have heard about green supply chain practices in industries.	-1.88402	0.060093
6. Industry 4.0 technologies can help reduce waste and pollution in the FMCG sector.	1.180988	0.238121
7. Automation and data-driven technologies lead to more sustainable supply chain operations.	1.685006	0.092558
8. The adoption of Industry 4.0 will encourage eco-friendly practices in FMCG companies.	2.650128	0.008279
9. Industry 4.0 has a positive impact on resource efficiency and energy management.	3.32425	0.000946
10. Students should be educated on the importance of sustainability in industrial practices.	-0.27764	0.78139
11. Green supply chain practices are essential for environmental protection.	3.725889	0.000215
12. FMCG companies have a responsibility to implement green logistics and packaging.	3.603521	0.000343
13. Consumers are more likely to support companies with sustainable practices.	3.235253	0.001289
14. Green supply chain adoption can improve a companyâ€™s brand image.	3.462296	0.000577
15. Implementing green practices in supply chains should be mandatory.	1.001845	0.316861
16. Students can contribute to sustainable practices through conscious consumption.	3.022729	0.002622
17. Future managers and professionals should be trained in Industry 4.0 and sustainability.	0.366904	0.713833
18. Educational institutions should include Industry 4.0 and green supply chain topics in their curriculum.	0	1
19. Young people have a role in encouraging companies to adopt sustainable technologies.	2.916186	0.003689
20. I am interested in learning more about how technology can make supply chains greener.	3.61952	0.000323

Key Findings

- Statistically Significant Results:
  Almost all the items in the questionnaire showed statistically significant t-values ($p < 0.05$), suggesting that respondents' views deviated significantly from neutrality.
- Positive Mean Values:
  The mean scores for most items were above 3, indicating a general agreement among respondents on the positive role of Industry 4.0 in enhancing supply chain sustainability in the FMCG sector.
- Strongest Agreements
  1. High agreement was observed on items related to education and training in sustainability, such as:
     - "Students should be educated on sustainability in industrial practices."
     - "Future managers should be trained in Industry 4.0 and sustainability."
  2. This reflects widespread support for embedding sustainability and digitalization in education and professional development.
- Support for Green Supply Chains:
  Items emphasizing green logistics, brand image, and consumer preference for sustainable practices also received significantly high mean scores, confirming a positive perception of sustainable operations.

Conclusion

The t-test results clearly demonstrate that respondents strongly support the integration of Industry 4.0 technologies in FMCG supply chains to promote sustainability. There is also a notable recognition of the role that education, technology, and consumer behaviour play in accelerating this transition. These

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statistically significant findings reinforce the importance of developing strategic policies and training programs aligned with digital and environmental priorities.

Conclusion

The research confirmed that content strategy significantly influences consumer engagement on social media platforms. Personalized, relevant, high-quality content aligned with users' interests was found to be the most powerful driver of engagement. Interactive posts, promotional offers, behind-the-scenes content, and customer testimonials were particularly effective in fostering participation and building trust. Furthermore, frequent posting, brand responsiveness, and personalization strongly correlated with positive consumer perceptions and loyalty. The findings also revealed that overly promotional content, excessive advertisements, inconsistent posting, and lack of brand interaction were major triggers for user disengagement. Occupation-based analysis showed that both employed and unemployed individuals prioritize relevance, quality, and personalization, but unemployed users also valued motivational elements like rewards and positive reinforcement. Overall, the study concludes that for brands to build lasting relationships, they must adopt a customer-centric content strategy — balancing promotional efforts with authenticity, entertainment, education, and interactive engagement — while maintaining consistency and responsiveness across digital platforms.

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