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An Evaluation of Sustainability Initiatives Adopted by the Delhi Metro Rail Corporation in Urban Public Transport

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Abstract
Urban public transport systems play a critical role in addressing congestion, pollution, and sustainability challenges in rapidly growing cities like Delhi. The Delhi Metro Rail Corporation has implemented several sustainability initiatives, including renewable energy use, eco-friendly operations, and community-oriented measures, yet their overall effectiveness required systematic evaluation. This study assesses the sustainability initiatives adopted by the Delhi Metro Rail Corporation across environmental, operational, and social dimensions. A mixed-method research design was employed, combining a structured questionnaire survey of 421 metro users collected through a snowball sampling method with secondary data from official reports and academic literature. Quantitative analysis using SPSS included descriptive statistics, correlation, regression, and hypothesis testing to examine the relationship between sustainability initiatives and overall system performance. The findings reveal that DMRC's sustainability initiatives have a significant positive contribution to the sustainability performance of the Delhi Metro. Initiatives related to clean energy adoption, waste management, technological advancement, and community engagement were found to be particularly influential in promoting sustainable urban mobility. Other measures such as eco-friendly practices, tree plantation, water conservation, and noise reduction also supported sustainability outcomes, though with varying levels of impact. In contrast, environmental audits and green building certifications showed comparatively limited perceived influence. Overall, the study confirms that DMRC's sustainability initiatives strengthen sustainable urban transport and highlights the need for continuous improvement and focused policy support.

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Keywords: Urban Public Transport Systems, Pollution, Sustainability, Rapidly Growing, Delhi Metro Rail Corporation, Renewable Energy, Tree Plantation and Water Conservation

1. Introduction

Urban public transport plays a key role in promoting sustainable urban development in large cities. Rapid urban growth, rising travel demand, and environmental stress have increased pressure on transport systems in Delhi. In this context, metro rail systems are viewed as cleaner and more efficient alternatives to private vehicles. The Delhi Metro has transformed daily mobility by offering reliable, high-capacity, and energy-efficient transport across the city. Sustainability in urban transport goes beyond emission reduction and includes social inclusion, accessibility, and long-term system resilience. Studies on Delhi's transport structure show that sustainable outcomes depend on integrated planning, land-use coordination, and equitable access for diverse user groups (Chaudhari *et al*., 2025) [1]. As cities expand, public transport agencies must align operational efficiency with environmental and social goals. The experience of metro systems highlights how planned rail networks can reduce congestion, fuel use, and travel time, while supporting compact urban growth. These aspects make the Delhi Metro an important case for examining sustainability initiatives in an Indian megacity context.

Globally, urban rail systems are recognized as anchors of sustainable transport strategies. Lessons from cities such as Hong Kong, London, and New York show that metro systems contribute to lower carbon emissions and improved urban livability when supported by strong governance and policy continuity (Sharma & Newman, 2017) [2]. In Delhi, sustainability efforts are closely linked with energy use, station design, regenerative braking, and increasing adoption of renewable power. However, infrastructure alone does not ensure sustainability. Service quality, network coverage, and last-mile connectivity strongly influence public acceptance and system effectiveness. Research on the Delhi-NCR region indicates that gaps in feeder services and pedestrian access can limit the full sustainability potential of metro systems (Choudhary *et al*., 2025) [3]. Therefore, evaluating the sustainability initiatives adopted by Delhi Metro Rail Corporation requires a holistic approach. Such an evaluation helps assess how environmental, social, and operational measures collectively support sustainable urban public transport and inform future policy and planning decisions.

1.1. Background of Urban Public Transport and Sustainability in Delhi Metro Rail Corporation

Urban public transport in Delhi has evolved as a response to rapid urban growth, traffic congestion, and severe environmental stress. The expansion of the metro system marked a major shift toward sustainable mobility by offering high-capacity, energy-efficient, and reliable public transport. The Delhi Metro has influenced travel behavior, reduced dependence on private vehicles, and supported compact urban development through transit-oriented growth. Its role extends beyond mobility to shaping social inclusion, accessibility, and urban form, making it a key driver of sustainable urban transformation in the capital city (Begam *et al*., 2024) [4]. From a sustainability viewpoint, urban rail systems also contribute to lower emissions and improved operational efficiency by reducing road traffic load. Studies highlight that rail-based systems in Delhi can support not only passenger movement but also efficient urban logistics, further reducing congestion and fuel use (Singh & Gupta, 2020) [5]. Within this broader context, the Delhi Metro Rail Corporation represents a central institutional effort to align urban transport development with long-term sustainability objectives.

1.2. Concept of Sustainability in Urban Rail-Based Public Transport Systems

Sustainability in urban rail-based public transport refers to the ability of metro systems to meet present mobility needs without harming future social, environmental, and economic balance. Urban rail systems are considered sustainable due to their high passenger capacity, lower energy use per passenger, and reduced dependence on fossil-fuel-based road transport. In Indian cities, metro rail plays a vital role in reducing traffic congestion, air pollution, and travel time while improving accessibility across income groups. Sustainability also includes social aspects such as affordability, safety, inclusiveness, and integration with other transport modes. Well-planned metro systems support compact urban growth and encourage a shift from private vehicles to public transport, strengthening long-term urban mobility outcomes (Kuriakose & Bhattacharjee, 2021) [6].

From an operational perspective, sustainability in metro systems is closely linked to performance efficiency and system reliability. Energy-efficient rolling stock, regenerative braking, optimized scheduling, and improved station design contribute to lower operational emissions and cost efficiency. Performance assessment of Indian metro systems shows that sustainability depends not only on infrastructure expansion but also on service quality, punctuality, and passenger satisfaction. Financial sustainability is equally important, requiring balanced fare structures, non-fare revenue, and efficient asset management. Studies indicate that continuous performance monitoring helps metro systems improve resource use and environmental outcomes while maintaining service standards (Ansari & Ghodmare, 2023) [7]. Together, these dimensions define sustainability as a comprehensive framework guiding the planning, operation, and evaluation of urban rail-based public transport systems.

1.3. Growth of Delhi Metro and Its Role in Urban Mobility

The growth of the Delhi Metro represents a major shift in the city's urban transport system. Introduced to address rising congestion and uncontrolled urban expansion, the metro provided a structured and high-capacity alternative to road-based travel. Its phased expansion connected residential, commercial, and industrial zones, improving daily commuting efficiency. The metro also influenced urban growth patterns by encouraging development along transit corridors and reducing travel time across the city. Research shows that the Delhi Metro has played a significant role in managing urban growth by supporting planned expansion and limiting excessive dependence on private vehicles (Rahman, 2017) [8].

As the network expanded, its role in urban mobility became more strategic. The metro improved accessibility for diverse population groups by offering reliable, safe, and time-efficient transport. Integration with feeder buses, interchange stations, and multimodal hubs strengthened last-mile connectivity and enhanced system usability. From a management perspective, metro systems require coordinated planning, operational efficiency, and long-term vision to sustain mobility benefits. Strategic management practices in metro operations help balance service quality, financial viability, and environmental responsibility, reinforcing the metro's role as the backbone of urban mobility (Tiwari, 2024) [9].

Beyond mobility, the Delhi Metro has contributed to broader urban transformation in the Delhi-NCR region. The expansion of metro corridors has influenced land use, real estate development, and population distribution across peripheral areas. Studies indicate that metro connectivity has accelerated urbanization in surrounding regions while improving regional integration and mobility equity (Rana *et al*., 2022) [10]. Within this evolving urban landscape, the Delhi Metro Rail Corporation has emerged as a central institution shaping sustainable urban mobility through network growth, operational planning, and integrated transport development.

1.4. Need for Sustainable Transport Solutions in Rapidly Growing Cities

Rapidly growing cities face intense pressure from rising population, travel demand, and limited urban space. Conventional transport systems increase congestion, pollution, and energy use. Sustainable transport solutions are essential to balance mobility needs with environmental

protection, social equity, and economic efficiency. These solutions support long-term urban livability and resilient city growth.

1. **Reducing Environmental Impact:** Urban transport is a major source of air pollution and greenhouse gas emissions. Sustainable transport systems reduce fuel consumption and emissions by promoting public transport, non-motorized travel, and energy-efficient technologies. Cleaner transport improves urban air quality and public health while supporting climate goals in fast-growing cities (Joshi *et al*., 2017) [11].
2. **Managing Traffic Congestion:** Rapid urbanization leads to increased private vehicle use and road congestion. Sustainable transport emphasizes mass transit systems that move more people using less space. Metro rail and integrated public transport reduce traffic volume, travel delays, and infrastructure stress in dense metropolitan areas (Rajesh *et al*., 2019) [12].
3. **Ensuring Social Inclusion and Accessibility:** Sustainable transport systems improve access to jobs, education, and services for all social groups. Affordable and reliable public transport reduces mobility inequality. Inclusive transport planning ensures that urban growth benefits both central and peripheral populations equally (Rani, 2022) [13].
4. **Supporting Economic Efficiency:** Efficient transport systems lower travel time and operating costs for users and cities. Sustainable mobility reduces fuel imports, infrastructure maintenance costs, and productivity losses caused by congestion. This strengthens urban economies and supports long-term financial stability (Joshi *et al*., 2017) [11].
5. **Strengthening Urban Governance and Planning:** Sustainable transport requires coordinated governance, policy integration, and long-term planning. Strong institutional frameworks help align transport investments with land use, environmental goals, and public needs. Good governance ensures effective implementation and continuous system improvement (Rani, 2022) [13].

1.5. Environmental Challenges Linked with Urban Transportation in Delhi

Urban transportation in Delhi faces serious environmental challenges due to rapid motorization and heavy dependence on road-based travel. Transport activities contribute significantly to air pollution, energy use, and greenhouse gas emissions, placing pressure on urban ecological systems. The interaction between transport, energy demand, and resource use has intensified environmental stress, affecting air quality and urban sustainability outcomes (Ramaswami *et al*., 2017) [14]. Road transport emissions are closely linked with rising health risks, including respiratory and cardiovascular diseases, especially among vulnerable urban populations. Studies show that prolonged exposure to traffic-related pollution increases public health burdens and reduces overall quality of life in cities (Solanki *et al*., 2016) [15]. In addition, policy debates on air pollution in Delhi highlight gaps in coordination, implementation, and clarity of transport-related environmental strategies. Weak integration between transport planning and environmental policy has limited effective mitigation of pollution impacts (Weible *et al*., 2016) [16]. These challenges underline the urgent need for cleaner, efficient, and well-governed urban transport systems to reduce environmental damage and support sustainable urban development in Delhi.

2. Systematic Literature Review

Chaudhari (2025) [1] provides a recent and comprehensive foundation for evaluating sustainability initiatives in Delhi's urban public transport system. The literature consistently identifies the Delhi Metro as a central intervention for addressing congestion, air pollution, and social exclusion in a rapidly growing megacity. Sustainability initiatives highlighted include energy-efficient train operations, regenerative braking systems, green-certified stations, and promotion of public transport over private vehicles. Scholars argue that sustainability in metro systems is multidimensional, extending beyond emission reduction to include inclusivity, affordability, and accessibility. Comparative studies of global metro systems demonstrate that rail-based transport supports compact urban form and reduced car dependency when supported by coherent policy frameworks (Sharma & Newman, 2017) [2]. Environmental systems research further links metro-based mobility with reduced pressure on urban energy and resource flows, strengthening long-term ecological balance (Ramaswami *et al*., 2017) [14]. The literature emphasizes that institutional capacity and policy alignment are critical for sustaining these initiatives. Overall, studies position the Delhi Metro Rail Corporation as a key public agency whose sustainability initiatives reflect an integrated approach combining technology, planning, and governance.

Choudhary (2025) [3] shifts the sustainability discussion toward service supply and infrastructure effectiveness, particularly emphasizing last-mile connectivity. Literature indicates that while metro systems are inherently energy efficient, their sustainability impact depends heavily on user access and system integration. In the Delhi-NCR region, gaps in feeder services, pedestrian infrastructure, and intermodal coordination reduce the full environmental and social benefits of the metro network. Urban transformation studies note that metro expansion has significantly altered travel behavior and land-use patterns, encouraging transit-oriented development and reduced travel distances (Begam *et al*., 2024) [4]. However, unequal connectivity across regions limits inclusive mobility outcomes. Research on urban rail-based freight distribution highlights an additional sustainability dimension, suggesting that metro-aligned logistics planning can reduce road congestion and fuel consumption (Singh & Gupta, 2020) [5]. Together, these studies argue that sustainability initiatives must move beyond infrastructure creation to include service quality, network integration, and policy support. Evaluating DMRC initiatives therefore requires attention to how physical infrastructure and operational planning jointly influence environmental performance and social accessibility.

Tiwari (2024) [9] examines sustainability through the lens of strategic management and long-term urban mobility planning. The literature stresses that metro systems must remain operationally efficient and financially viable to sustain environmental benefits over time. Key initiatives include optimized scheduling, energy management systems, predictive maintenance, and diversification of non-fare revenue. Performance-based evaluations of Indian metro systems show that punctuality, reliability, and passenger satisfaction strongly influence public transport adoption and sustainability outcomes (Ansari & Ghodmare, 2023) [7].

When service performance weakens, commuters tend to revert to private vehicles, undermining emission reduction goals. Earlier studies on Delhi Metro growth highlight its success in reducing travel time and supporting orderly urban expansion (Rahman, 2017) [8]. Governance-focused research further emphasizes the role of transparent decision-making and inter-agency coordination in sustaining transport reforms (Rani, 2022) [13]. This body of literature suggests that sustainability initiatives must be embedded within strategic and institutional frameworks. Hence, evaluation of DMRC initiatives should include managerial effectiveness alongside environmental and social indicators.

Rana (2022) [10] situates the Delhi Metro within broader urbanization and regional development processes. Research shows that metro expansion has accelerated growth in peripheral areas, improving regional accessibility and reducing spatial inequality. At the same time, unplanned expansion around metro corridors can create new sustainability challenges if not guided by land-use regulation. Studies on India's metro systems underline their role in reducing vehicular emissions and encouraging modal shift toward public transport (Kuriakose & Bhattacharjee, 2021) [6]. Comparative analyses of metropolitan transport systems highlight that sustainable outcomes depend on aligning transport investments with environmental policy and urban planning goals (Rajesh *et al*., 2019) [12]. Health-based research continues to warn that persistent road transport dependence exposes urban populations to pollution-related risks (Solanki *et al*., 2016) [15]. Policy narrative studies further emphasize the need for clear sustainability frameworks to guide implementation and public trust (Weible *et al*., 2016) [16]. Overall, the literature presents Delhi Metro sustainability initiatives as impactful yet context-sensitive, requiring integrated planning, governance support, and continuous evaluation.

3. Problem Statement

Urban transportation in Delhi faces growing challenges due to rapid urbanization, rising travel demand, traffic congestion, and severe environmental degradation. Although the Delhi Metro Rail Corporation has implemented several sustainability initiatives such as energy-efficient operations, renewable energy use, and green station design, their overall effectiveness has not been systematically evaluated. Existing studies largely focus on network expansion or ridership growth, with limited integrated assessment of environmental, social, and operational sustainability outcomes. The absence of a comprehensive evaluation framework makes it difficult to identify strengths, gaps, and areas requiring policy and operational improvement in DMRC's sustainability efforts.

4. Significance of the Study

This study is significant as it provides a structured evaluation of sustainability initiatives adopted by the Delhi Metro Rail Corporation within the context of urban public transport. By examining environmental, social, and operational dimensions together, the research offers insights into how metro systems can contribute to sustainable urban mobility. The findings can support policymakers and transport planners in refining sustainability strategies, improving service integration, and strengthening governance mechanisms. Additionally, the study contributes to academic literature by developing evidence relevant to Indian megacities, offering a reference framework for evaluating sustainability practices in other urban rail systems.

5. Objective

To assess the sustainability initiatives undertaken by the Delhi Metro Rail Corporation (DMRC)

6. Hypothesis

1. H_0: The sustainability initiatives undertaken by DMRC is not significantly contribute to the sustainability performance of the Delhi Metro.
2. H_1: The sustainability initiatives undertaken by DMRC significantly contribute to the sustainability performance of the Delhi Metro.

7. Methodology

This study adopts a systematic methodology to evaluate the sustainability initiatives implemented by the Delhi Metro Rail Corporation in urban public transport. A mixed-method research approach was used to ensure a comprehensive assessment of sustainability across environmental, operational, and financial dimensions. Quantitative data were gathered through a structured commuter survey to capture user perceptions, while qualitative insights were drawn from official DMRC reports, policy documents, and published studies. This combined approach enabled triangulation of findings and improved the reliability of results.

7.1. Research Method

A structured survey method was employed to obtain measurable and comparable responses from Delhi Metro users. The questionnaire was developed using a five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5). The survey assessed commuter perceptions related to environmental sustainability measures, service efficiency, fare affordability, operational reliability, and overall satisfaction. Demographic variables such as age, gender, income, education, occupation, and area of residence were included to allow subgroup-wise analysis.

7.2. Research Strategy

A cross-sectional research strategy was adopted, with data collected at a single point in time. This strategy facilitated an assessment of the current sustainability performance of the Delhi Metro system. Statistical techniques such as correlation and regression analysis were applied to examine relationships between sustainability initiatives and outcomes including commuter satisfaction, perceived service quality, and operational effectiveness.

7.3. Questionnaire Design

The questionnaire was designed in accordance with the study objective and sustainability indicators identified from literature. Questions were framed in simple and unambiguous language to ensure clarity and respondent understanding. A preliminary review was conducted to refine question structure and ensure content validity before final distribution.

7.4. Sampling Design

Convenience sampling supported by a snowball technique was used to reach active Delhi Metro users across the National Capital Region. Initial respondents were encouraged to share the survey with other regular commuters, enabling wider coverage. A total of 421 valid responses were collected.

7.5. Data Collection

Primary data were collected through Google Forms and limited in-person interactions across Delhi, Gurugram, Noida, Faridabad, Ghaziabad, Bahadurgarh, and Ballabhgarh. Participation was voluntary, and confidentiality was maintained. Secondary data were sourced from DMRC publications, government reports, and academic literature.

7.6. Type of Study

Snowball sampling will recruit eligible participants through referrals, collecting cross-sectional data at one time using a five-point Likert scale.

7.7. Data Analysis

Data were analyzed using SPSS software. Descriptive statistics summarized demographic profiles and response trends. Correlation analysis identified relationships among sustainability variables, while regression analysis evaluated the impact of environmental, operational, and financial sustainability practices on overall system performance.

7.8. Results

Table 1: Demography

Category	Parameters	Frequency	Percent	Category	Parameters	Frequency	Percent
Gender	Male	228	54.2	Marital status	Married	287	68.2
	Female	193	45.8		Unmarried	134	31.8
	Total	421	100.0		Total	421	100.0
Qualification	High School	78	18.5		Gurugram	83	19.7
	Diploma	65	15.4		Noida	56	13.3
	Graduation	159	37.8		Faridabad	25	5.9
	Master	97	23.0		Ghaziabad	28	6.7
	PhD	22	5.2		Bahadurgarh	18	4.3
	Total	421	100.0		Ballabhgarh	16	3.8
Number of metro line use	Single line	82	19.5	Reach metro station	Walk	54	12.8
	Double line	187	44.4		Own Vehicle	60	14.3
	Triple line	117	27.8		Public Transport	237	56.3
	More than triple line	35	8.3		Ola/Uber Cab	70	16.6
	Total	421	100.0		Total	421	100.0

Table 1 presents the demographic profile of 421 Delhi Metro users, reflecting wide variation across personal, spatial, and travel-related characteristics. Gender distribution shows 54.2% male and 45.8% female respondents, indicating balanced participation. In terms of marital status, married respondents constitute 68.2%, while 31.8% are unmarried, suggesting that metro usage is dominant among working adults with family commitments. Educational qualification data reveal a relatively educated commuter base, with graduates (37.8%) forming the largest group, followed by master's degree holders (23.0%), high school educated respondents (18.5%), diploma holders (15.4%), and PhD holders (5.2%). Area-wise distribution shows that most respondents are from Delhi (46.3%), followed by Gurugram (19.7%), Noida (13.3%), Ghaziabad (6.7%), Faridabad (5.9%), Bahadurgarh (4.3%), and Ballabhgarh (3.8%), indicating extensive NCR-wide metro usage. Regarding travel patterns, 44.4% of respondents use double metro lines, 27.8% use triple lines, 19.5% use a single line, and 8.3% use more than three lines, reflecting varied trip lengths and network dependency. Access to metro stations is primarily through public transport (56.3%), followed by Ola or Uber cabs (16.6%), own vehicles (14.3%), and walking (12.8%), highlighting the importance of last-mile connectivity options.

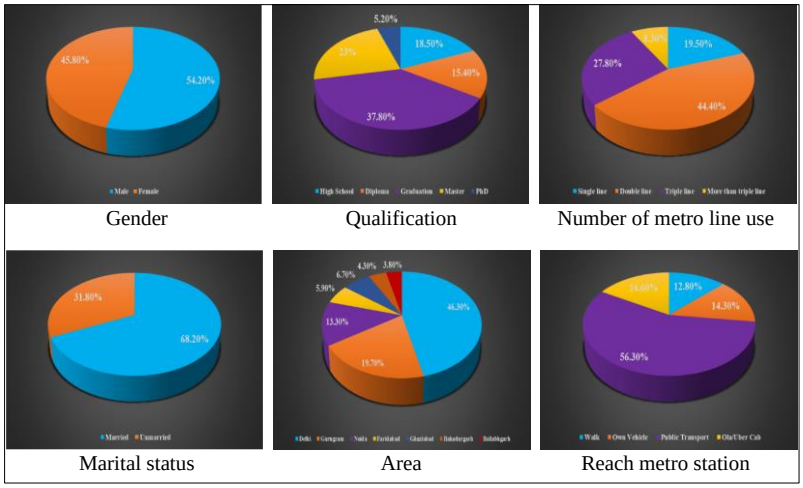

Fig 1: Demography

Table 2: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.500[a]	.250	.231	1.146

Predictors: (Constant), Green Building Certifications, Community Engagement, Water Conservation, Environmental Audits, Promotion of Eco-Friendly, Adopting Advanced Technologies, Tree Plantation Drives, Waste Management Practices, Focus on Noise Reduction, Solar Energy

Table 3: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	178.939	10	17.894	13.633	.000
	Residual	538.144	410	1.313		
	Total	717.083	420			

1. **Dependent Variable:** DMRC's Sustainability Initiatives
2. **Predictors:** (Constant), Green Building Certifications, Community Engagement, Water Conservation, Environmental Audits, Promotion of Eco-Friendly, Adopting Advanced Technologies, Tree Plantation Drives, Waste Management Practices, Focus on Noise Reduction, Solar Energy

Tables 2 and 3 summarize the regression results evaluating sustainability initiatives adopted by DMRC. The model shows a moderate relationship between sustainability factors and overall initiatives (R = 0.500). An R^2 value of 0.250 indicates that 25% of variation in DMRC's sustainability initiatives is explained by variables such as solar energy use, green building certifications, waste management, and advanced technologies. The adjusted R^2 of 0.231 confirms model stability. The ANOVA results show a significant F value of 13.633 with p = 0.000, indicating that the regression model is statistically significant. Overall, the findings confirm that the selected environmental and operational sustainability parameters jointly influence DMRC's sustainability performance.

Table 4: Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients Beta	t	Sig.
	B	Std. Error			
(Constant)	.378	.264		1.431	.153
Waste Management Practices	.104	.045	.109	2.343	.020
Adopting Advanced Technologies	.100	.042	.109	2.368	.018
Community Engagement	.111	.050	.106	2.223	.027
Promotion of Eco-Friendly	.109	.048	.107	2.256	.025
Solar Energy	.130	.050	.123	2.592	.010
Environmental Audits	.059	.049	.057	1.194	.233
Focus on Noise Reduction	.091	.046	.092	1.989	.047
Green Building Certifications	.000	.048	.000	-.006	.995
Tree Plantation Drives	.096	.048	.097	2.023	.044
Water Conservation	.095	.046	.097	2.081	.038

Dependent Variable: DMRC's Sustainability Initiatives

Table 4 presents the regression analysis explaining the influence of selected sustainability parameters on DMRC's sustainability initiatives using standardized beta coefficients, t-values, and significance levels. Solar Energy emerges as the most influential factor with the highest standardized beta (β = 0.123), a strong t-value (t = 2.592), and high statistical significance (Sig. = 0.010), indicating its critical role in strengthening sustainable metro operations. Waste Management Practices (β = 0.109, t = 2.343, Sig. = 0.020) and Adopting Advanced Technologies (β = 0.109, t = 2.368, Sig. = 0.018) also show significant positive impacts, highlighting the importance of efficient resource handling and technological innovation. Community Engagement demonstrates a meaningful influence (β = 0.106, t = 2.223, Sig. = 0.027), reflecting the role of public participation in sustainability outcomes. Promotion of Eco-Friendly practices (β = 0.107, t = 2.256, Sig. = 0.025) further contributes positively to overall sustainability performance. Tree Plantation Drives (β = 0.097, t = 2.023, Sig. = 0.044) and Water Conservation measures (β = 0.097, t = 2.081, Sig. = 0.038) are also statistically significant, emphasizing ecological balance initiatives. Focus on Noise Reduction shows marginal but significant influence (β = 0.092, t = 1.989, Sig. = 0.047). However, Environmental Audits (Sig. = 0.233) and Green Building Certifications (Sig. = 0.995) do not exhibit a significant effect, suggesting limited perceived impact on DMRC's sustainability initiatives.

Table 5: Hypothesis Testing with key variable "DMRC's Sustainability Initiatives"

Variable	t-value	Sig. (p-value)	Pearson r	Spearman ρ	χ^2 Value	Remark H_1)
Waste Management Practices	2.343	0.02	0.272	0.274	54.7	Accepted
Adopting Advanced Technologies	2.368	0.018	0.272	0.274	49.762	Accepted
Community Engagement	2.223	0.027	0.294	0.287	61.966	Accepted
Promotion of Eco-Friendly	2.256	0.025	0.282	0.283	61.616	Accepted
Solar Energy	2.592	0.01	0.304	0.3	59.981	Accepted
Environmental Audits	1.194	0.233	0.253	0.254	47.416	Rejected
Focus on Noise Reduction	1.989	0.047	0.254	0.27	64.409	Accepted
Green Building Certifications	-0.006	0.995	0.185	0.188	55.766	Rejected
Tree Plantation Drives	2.023	0.044	0.293	0.292	70.381	Accepted
Water Conservation	2.081	0.038	0.258	0.258	40.584	Accepted

Table 5 explains hypothesis testing using χ^2, Pearson r, and significance values for all sustainability parameters related to DMRC's Sustainability Initiatives. Solar Energy shows the strongest association with sustainability (r = 0.304, χ^2 = 59.981, Sig. = 0.010), confirming hypothesis acceptance. Community Engagement also demonstrates a meaningful relationship (r = 0.294, χ^2 = 61.966, Sig. = 0.027). Tree Plantation Drives record a strong association with sustainability (r = 0.293, χ^2 = 70.381, Sig. = 0.044). Promotion of Eco-Friendly practices is significant (r = 0.282, χ^2 = 61.616, Sig. = 0.025). Waste Management Practices show a positive and significant relationship (r = 0.272, χ^2 = 54.700, Sig. = 0.020), while Adopting Advanced Technologies also contributes meaningfully (r = 0.272, χ^2 = 49.762, Sig. = 0.018). Focus on Noise Reduction exhibits a moderate association (r = 0.254, χ^2 = 64.409, Sig. = 0.047), and Water Conservation remains significant (r = 0.258, χ^2 = 40.584, Sig. = 0.038). In contrast, Environmental Audits (r = 0.253, χ^2 = 47.416, Sig. = 0.233) and Green Building Certifications (r = 0.185, χ^2 = 55.766, Sig. = 0.995) show weak significance, leading to hypothesis rejection.

8. Conclusion

This study evaluated the sustainability initiatives adopted by the Delhi Metro Rail Corporation in urban public transport using responses from 421 metro users across the National Capital Region. The demographic profile indicates balanced participation, with 54.2% male and 45.8% female respondents. A majority of commuters were married (68.2%), reflecting regular metro usage among working adults. Educationally, graduates (37.8%) and postgraduates (23.0%) formed the largest groups, indicating an informed user base. Spatial coverage was extensive, with 46.3% respondents from Delhi, followed by Gurugram (19.7%) and Noida (13.3%). Travel patterns show strong network dependency, as 44.4% of users relied on double-line travel and 27.8% on triple-line travel. Access to stations was mainly through public transport (56.3%), highlighting the importance of integrated and sustainable last-mile connectivity.

The results clearly demonstrate that sustainability initiatives undertaken by DMRC significantly contribute to the sustainability performance of the Delhi Metro, leading to acceptance of hypothesis (H_1). The regression model indicates a moderate relationship (R = 0.500), with 25% of variation in sustainability performance explained by the selected initiatives and a statistically significant model (p = 0.000). Among the key factors, Solar Energy emerged as the most influential factor (β = 0.123, Sig. = 0.010), followed by Waste Management Practices (β = 0.109, Sig. = 0.020), Adopting Advanced Technologies (β = 0.109, Sig. = 0.018), and Community Engagement (β = 0.106, Sig. = 0.027). Hypothesis testing further supports the role of eco-friendly promotion, tree plantation drives, water conservation, and noise reduction measures. In contrast, environmental audits and green building certifications showed limited statistical influence, indicating the need for improved implementation and awareness.

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