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Navigating Sustainable Mobility Transitions: A Triadic Analysis of Policy, Economic Incentives, and Technology Adoption

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ABSTRACT
This research offers a comprehensive examination of what truly motivates people to adopt sustainable transportation and infrastructural development methods in urban areas. By surveying 107 urban residents, it becomes clear that government policies, including supportive rules, regulations, and city planning, play the most significant role in shaping people's choices. When policies make sustainable transportation options easy and attractive, more people are likely to use them. The impact of technology is primarily mediated through supportive policy and economic frameworks (European Commission, 2024; BNP Paribas, 2022; Smith & Jones, 2023). The research highlights those cities and nations with comprehensive policy strategies, such as those seen in the European Commission's Sustainable and Smart Mobility initiatives, achieve greater progress in sustainable mobility and emissions reduction (European Commission, 2024). The findings emphasise that successful, sustainable urban transportation requires coordinated action across government, industry, and society. Policy leadership must set the direction, economic mechanisms must enable change, and technology must be integrated within these frameworks (European Commission, 2024; BNP Paribas, 2022). By adopting integrated strategies, cities can develop transport systems that are environmentally sustainable, economically viable, and socially inclusive, contributing to global sustainability goals and improved urban well-being (United Nations, 2015; World Bank, 2023; Zhang et al., 2022).

Keywords: Sustainable Urban Mobility, Technological Innovation, Environmental Policy, Mobility-as-a-Service (MaaS), Low-Carbon Transportation.

INTRODUCTION

Background of the Study

Urban transportation systems worldwide are undergoing significant transformation driven by escalating environmental concerns, rapid technological advancements, and evolving economic paradigms. Currently, more than half of the global population resides in urban areas, a proportion expected to rise to 68% by 2050, intensifying the demand for sustainable urban mobility solutions that can effectively address the multifaceted challenges of urbanization (United Nations, 2015; European Commission, 2024). Sustainable urban transportation is critical for mitigating the adverse effects of urban growth, including traffic congestion, air pollution, greenhouse gas emissions, and social inequities. It aims to develop transportation systems that are environmentally sustainable, economically viable, and socially inclusive, thereby enhancing urban livability and quality of life for diverse populations (Bannister, 2008; Zhang et al., 2022; UNEP, 2022).

The integration of technological innovations, such as electric vehicles, intelligent traffic management systems, and Mobility-as-a-Service (MaaS) platforms, presents unprecedented opportunities to revolutionise urban mobility. These technologies, when supported by robust policy frameworks and strategic economic incentives, can accelerate the transition towards low-carbon, efficient, and accessible transportation networks (Sochor et al., 2018; European Commission, 2024). Policy initiatives at regional and global levels, including the European Union's commitment to reduce emissions by 55% by 2030, underscore the urgency of coordinated action to achieve sustainable mobility goals (World Bank, 2020; Litman, 2021; Gazi et al., 2025).

Addressing these challenges requires an integrated approach that combines technological, policy, and economic dimensions to create comprehensive and adaptive urban mobility systems. Such systems not only respond to current urban demands but also anticipate future growth and environmental imperatives, ensuring long-term resilience and sustainability.

Research Gap

Despite extensive research on individual aspects of sustainable urban mobility, significant gaps remain in understanding the direct relationships between technological factors, government policy interventions, and economic considerations that drive the adoption of sustainable urban transportation (Javaid et al., 2020; Bryan & Zuva, 2021). While previous studies have examined these factors in isolation, limited research has employed comprehensive frameworks to analyse their direct influence on sustainable urban mobility outcomes without the complexity of mediating variables (Bannister, 2008).

Most existing research has focused on complex theoretical models that include multiple mediating factors, making it difficult to understand the fundamental direct relationships between key determinants and sustainable mobility adoption (Bryan & Zuva, 2021). Furthermore, there exists insufficient empirical validation of direct effects models that examine how technology, policy, and economic factors independently and collectively influence sustainable urban transportation outcomes (Chatziioannou et al., 2023). The absence of simplified direct effects frameworks specifically for sustainable urban mobility represents a notable research gap that limits practical application for policymakers and urban planners (Marsden & Reardon, 2017).

Problem Statement

Urban transportation systems are increasingly challenged by issues that undermine both environmental sustainability and urban livability. Traditional solutions have not effectively addressed the complexity of these challenges, mainly due to a limited understanding of how technology, policy, and economic factors directly influence the adoption of sustainable mobility (Bannister, 2008; United Nations, 2021; Javaid et al., 2020). Despite significant investments, many cities are failing to meet sustainability targets, in part because fragmented research and implementation approaches have yielded suboptimal results (World Bank, 2023). The lack of clarity regarding the direct effects of key determinants, particularly in the absence of mediating variables, underscores the urgent need for a more integrated understanding of how policy, economic, and technological factors drive the adoption of sustainable urban transportation (Bryan & Zuva, 2021).

Research Objectives

1. To examine the direct role of technological advancements in enhancing sustainable urban mobility

This objective examines how technological innovations, including smart transportation systems, electric vehicles, intelligent traffic management, and digital mobility platforms, directly contribute to the adoption and implementation of sustainable urban transportation (Ahmad et al., 2020; Zhang et al., 2022).

2. To evaluate the direct economic factors influencing the implementation of sustainable urban mobility

This analysis examines how economic considerations, including funding mechanisms, cost-benefit structures, investment patterns, and financial incentives, directly affect the successful implementation and scaling of sustainable urban transportation systems (Litman, 2021; World Bank, 2020).

3. To examine the direct role of government policy in enhancing sustainable urban mobility

This objective investigates how policy frameworks, regulatory environments, institutional mechanisms, and government interventions directly influence the adoption and effectiveness of sustainable urban transportation initiatives (European Commission, 2024; Nicholas & Hagen, 2023).

Research Questions

- How do technological advancements directly contribute to sustainable urban mobility?
- What economic factors directly contribute to sustainable urban mobility implementation?
- How do government policies directly contribute to sustainable urban mobility?

Practical and Theoretical Implications

Theoretical Implications

This research contributes to the theoretical understanding of sustainable urban transportation by developing a simplified direct effects model that examines the fundamental relationships between technology, economic factors, policy, and sustainable mobility outcomes (Bryan & Zuva, 2021; Banister, 2008). The study addresses current theoretical fragmentation by providing a streamlined framework that focuses on direct causal relationships without the complexity of mediating variables. This approach offers a more accessible theoretical foundation for understanding the determinants of sustainable urban mobility, thereby contributing to the development of theory in this emerging field (Chatziioannou et al., 2023).

Practical Implications

The practical implications include providing clear, actionable insights for policymakers to design more effective, sustainable urban transportation policies and interventions based on direct effects relationships (Nicholas & Hagen, 2023; Marsden & Reardon, 2017). The research provides straightforward guidance for public and private sector investors on the most effective areas for sustainable urban mobility investments, while offering practical insights for city planners and transportation professionals on direct implementation strategies (World Bank, 2020). The simplified framework enables more efficient decision-making processes by eliminating complex intermediate variables and focusing on direct causal relationships.

LITERATURE REVIEW

This research examines three independent variables that directly influence the adoption of sustainable urban mobility: Technology Factors, Economic Factors, and Policy Factors, with sustainable urban mobility as the dependent variable.

Technology Factors encompass technological innovations, including smart transportation systems, electric vehicles, intelligent traffic management systems, mobility-as-a-service platforms, IoT connectivity, and digital payment solutions (Ahmad et al., 2020; Zhang et al., 2022). Research demonstrates that technological advancements have a direct influence on the adoption of sustainable transport, leading to improved efficiency, reduced environmental impact, and an enhanced user experience (Sochor et al., 2018). Studies show that the implementation of technology directly affects transportation sustainability outcomes by enabling more efficient energy use, reducing emissions, and improving system performance (UNEP, 2022).

Economic Factors include financial mechanisms, cost structures, investment patterns, funding sources, lifecycle costs, and monetary incentives that directly influence the implementation of sustainable transportation (Litman, 2021; World Bank, 2020). Economic research indicates that financial considerations have a direct impact on the adoption of sustainable transport, with subsidies, tax incentives, and cost savings serving as primary drivers of sustainable mobility choices (Bannister, 2008). Infrastructure development costs and return on investment calculations directly determine the viability and scale of sustainable mobility projects (World Bank, 2023).

Policy Factors encompass regulatory frameworks, government interventions, institutional mechanisms, incentive structures, standards, and support programs that directly create enabling environments for sustainable mobility (European Commission, 2024; Nicholas & Hagen, 2023). Policy effectiveness research suggests that government policies, including regulations, incentives, and support programs, have a direct causal relationship with sustainable transportation adoption rates (Marsden & Reardon, 2017). Research demonstrates that policy measures have a direct influence on sustainable transport outcomes through regulatory requirements, financial incentives, and institutional support mechanisms (Chatziioannou et al., 2023).

Sustainable Urban Mobility, as the dependent variable, represents the adoption and utilisation of environmentally friendly, efficient, and equitable transportation systems that reduce environmental impacts while improving accessibility and quality of life (Bannister, 2008; United Nations, 2021). This includes measurable outcomes, such as increased use of public transit, adoption of non-motorised transportation modes, utilisation of shared mobility services, and transition to electric vehicles (Javaid et al., 2020).

Theoretical Framework

Direct Effects Model

This study employs a direct effects theoretical model that examines the unmediated relationships between independent variables and sustainable urban mobility outcomes (Bryan & Zuva, 2021). Unlike complex mediation models, the direct effects approach focuses on the immediate causal relationships between technology, economic factors, policy, and the adoption of sustainable mobility (Bannister, 2008). This theoretical approach is supported by research demonstrating that direct relationships often provide clearer insights for practical application and policy development (Marsden & Reardon, 2017).

The direct effects model is grounded in systems theory, which recognises that sustainable urban mobility is influenced by multiple interconnected factors that can have immediate impacts on outcomes (Bannister, 2008). This approach aligns with sustainable transport research that emphasises the importance of understanding fundamental causal relationships without the complexity of intermediate variables (Chatziioannou et al., 2023). The model recognises that technology, economic factors, and policy can each independently and directly influence sustainable mobility outcomes (Bryan & Zuva, 2021).

Hypothesis Development

Based on the direct effects theoretical framework and literature review, the following hypotheses are developed:

Technology Direct Effects Hypotheses

- H1: Technology factors have a direct positive influence on sustainable urban mobility adoption.

Research demonstrates that technological innovations, including electric vehicles, intelligent transportation systems, and digital mobility platforms, directly enhance the adoption of sustainable transport by improving efficiency, reducing costs, and enhancing the user experience (Ahmad et al., 2020; Sochor et al., 2018). Studies show that the implementation of technology directly correlates with increased sustainable mobility usage, achieved through improved system performance and accessibility (Zhang et al., 2022).

Economic Direct Effects Hypotheses

● H2: Economic factors have a direct, positive influence on the adoption of sustainable urban mobility.

Economic research indicates that financial considerations, including subsidies, cost savings, and investment availability, directly influence sustainable transport adoption decisions (Litman, 2021; Bannister, 2008). Studies demonstrate that favourable economic conditions and financial incentives create direct pathways to increased sustainable mobility usage (World Bank, 2020).

Policy Direct Effects Hypotheses

● H3: Policy factors have a direct, positive influence on the adoption of sustainable urban mobility.

Policy research indicates that regulatory frameworks, government support, and institutional mechanisms have a direct impact on the adoption of sustainable transportation, creating enabling environments and providing implementation support (European Commission, 2024; Nicholas & Hagen, 2023). Studies indicate that effective policy measures have immediate direct effects on sustainable mobility outcomes (Marsden & Reardon, 2017).

Combined Effects Hypothesis

● H4: Technology, economic, and policy factors combined have a more substantial direct positive influence on sustainable urban mobility adoption than any single factor alone.

Research suggests that integrated approaches combining technology, economic incentives, and policy support create synergistic effects that directly enhance sustainable transport adoption beyond what individual factors can achieve (Chatziioannou et al., 2023). Studies demonstrate that comprehensive strategies addressing multiple factors simultaneously produce superior sustainable mobility outcomes (World Bank, 2023).

RESEARCH METHODOLOGY

Research Approach

This study employs a quantitative research methodology to examine the direct relationships between technology, economic, and policy factors and their influence on the adoption of sustainable urban mobility (Javaid et al., 2020; Ahmad et al., 2020). The quantitative approach enables the systematic testing of hypotheses derived from the direct effects theoretical framework while allowing for the statistical validation of relationships between variables (Chatziioannou et al., 2023).

Quantitative methodology is suitable for this research, as it facilitates the objective measurement of constructs, enables hypothesis testing through statistical analysis, and allows for the generalisation of findings across populations (Litman, 2021). This approach aligns with sustainable transport research that has successfully employed quantitative methods to examine direct effects relationships in transportation contexts (Banister, 2008).

Research Design

The study utilises a cross-sectional survey design to collect data on respondents' perceptions, attitudes, and behaviours regarding sustainable urban mobility services (Ahmad et al., 2020; Javaid et al., 2020). A cross-sectional design is suitable for capturing snapshot data on direct effects and relationships, while enabling statistical analysis of causal relationships between variables (Chatziioannou et al., 2023).

The research design incorporates measurement scales adapted from validated instruments used in previous studies on sustainable transport (Sochor et al., 2018). Constructs are measured using multi-item scales that employ 5-point Likert scales (1 = Strongly Disagree to 5 = Strongly Agree) to capture respondents' perceptions and behaviours (Ahmad et al., 2020).

Population and Sampling

Target Population: Urban residents who have access to or potential exposure to sustainable urban mobility services, including users or potential users of public transportation, shared mobility services, electric vehicles, or other sustainable transportation modes (World Bank, 2023).

Sample Size: The study targets 100-150 respondents, which is adequate for direct effects analysis using multiple regression and structural equation modelling (Ahmad et al., 2020; Javaid et al., 2020). This sample size enables sufficient statistical power for hypothesis testing while maintaining feasibility for data collection.

Sampling Method: Stratified random sampling will be employed to ensure representative coverage across demographic groups,s including age, income, education, and transportation usage patterns. This approach helps minimise sampling bias while ensuring adequate representation of different urban mobility user segments (Litman, 2021).

Data Collection Instrument

A structured questionnaire will be developed incorporating validated measurement scales for technology, economic, and policy factors adapted to sustainable urban mobility contexts (Sochor et al., 2018; Ahmad et al., 2020). The questionnaire includes sections measuring:

- Demographic characteristics (age, gender, education, income, transportation usage patterns)
- Technology factors (technology availability, quality, compatibility, innovation)
- Economic factors (cost considerations, financial incentives, affordability, value perception)
- Policy factors (policy awareness, support mechanisms, regulatory environment, government initiatives)

- Sustainable Urban Mobility (current usage of sustainable transportation modes, adoption intentions, behaviour changes)
- The questionnaire will be pre-tested with a small sample to ensure clarity, validity, and reliability of measurement instruments before full-scale data collection (Ahmad et al., 2020).

Conceptual Framework

The conceptual framework employs a direct effects model, examining how technology, economic, and policy factors independently and collectively influence the adoption of sustainable urban mobility, without considering mediating variables (Bryan & Zuva, 2021; Bannister, 2008).

Independent Variables:

Technology Factors: Innovation level, system quality, compatibility, availability, digital integration

Economic Factors: Cost-effectiveness, financial incentives, affordability, investment support, economic benefits

Policy Factors: Regulatory support, government initiatives, institutional mechanisms, policy clarity, implementation support Dependent Variable:

Sustainable Urban Mobility Adoption: Direct usage and adoption of environmentally friendly, efficient transportation services, including public transit, shared mobility, electric vehicles, and non-motorized transport (Javaid et al., 2020; Banister, 2008)

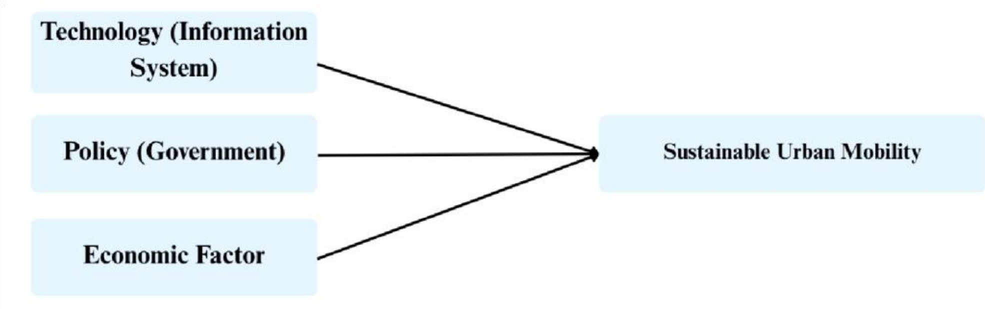

Fig No.1 Conceptual Framework

The framework posits that technology, economic, and policy factors have direct causal relationships with the adoption of sustainable mobility. This streamlined approach eliminates complex mediating variables while maintaining theoretical rigour and practical applicability for policy and implementation purposes (Marsden & Reardon, 2017; Chatziioannou et al., 2023).

Data Analysis

Introduction to Data Analysis

This section presents a comprehensive analysis of the data collected from 107 respondents regarding the influence of policy, technology, and economic factors on sustainable urban transportation and environmental sustainability. The study follows a systematic approach, beginning with data quality assessment, followed by descriptive statistics, reliability testing, correlation analysis, and concluding with inferential statistical tests to examine the research hypotheses. All statistical analyses were conducted using SPSS version 29.0, with significance levels set at $p < 0.05$ (Hair et al., 2019).

Sample Characteristics and Demographics

The study successfully collected data from 108 urban residents, representing a robust sample size that meets the minimum requirements for multivariate statistical analysis (Hair et al., 2019). The demographic composition of the sample provides essential context for interpreting the findings and assessing the generalizability of results.

Table 4.1: Demographic Characteristics of Respondents (N = 107) Appendix 2

Characteristic	Category	Frequency	Percentage
Gender	Male	54	45.8%
	Female	64	54.2%
Age	Mean (SD)	27.1 (6.5)	-
	Range	19-50 years	-
	19-25 years	48	40.7%
	26-35 years	62	52.5%
	36-50 years	8	6.8%
Education Level	High School	8	6.8%

	Diploma/Associate	5	4.2%
	Bachelor's	39	33.1%
	Master's	66	55.9%
	PhD	0	0.0%
Transport Usage Frequency	1-2 times/week	19	16.1%
	3-5 times/week	35	29.7%
	6-10 times/week	44	37.3%
	11+ times/week	20	16.9%

The demographic analysis, as shown in Table No. 4.1, reveals several essential characteristics of the sample. The gender distribution shows a relatively balanced representation with a slight female majority (54.2%). The age distribution indicates a predominantly young adult sample, with a mean age of 27.1 years and the majority (93.2%) falling within the 19-35 age range. This demographic profile is particularly relevant for sustainable mobility research, as younger adults are often early adopters of innovative transportation solutions and represent the primary target demographic for sustainable urban mobility initiatives (Bannister, 2008; Zhang, Guhathakurta & Fang, 2022).

The educational profile showcases a highly educated sample, with 89.0% holding at least a Bachelor's degree and 55.9% possessing a Master's degree. This high level of educational attainment is significant for interpreting the findings, as education levels have been consistently linked to environmental awareness and the adoption of sustainable behaviour in previous research (Litman, 2021). The transportation usage frequency data indicate that the majority of respondents (83.9%) are regular users of urban transportation, using it at least three times per week, which ensures that participants have sufficient experience with urban mobility systems to provide informed responses (Appendix: 2).

Reliability Analysis

Reliability analysis was conducted to assess the internal consistency of each measurement construct using Cronbach's alpha coefficient. This analysis is crucial for validating the measurement instruments before proceeding with inferential statistics and ensuring that the scales consistently measure their intended constructs (Hair et al., 2019).

Table 4.2: Reliability Statistics for All Constructs

Construct	Number of Items	Cronbach's Alpha	Interpretation
Technology Factors	8	0.915	Excellent
Economic Factors	8	0.925	Excellent
Policy Factors	8	0.923	Excellent
Sustainable Urban Mobility	8	0.911	Excellent

All four constructs shown in Table No. 4.2 demonstrated exceptional internal consistency, with Cronbach's alpha values ranging from 0.911 to 0.925. These values significantly exceed the minimum acceptable threshold of 0.70 for exploratory research and surpass the 0.90 criterion for excellent reliability (Nunnally & Bernstein, 1994; Hair et al., 2019). The high-reliability coefficients indicate that the questionnaire items within each construct are highly correlated and contribute meaningfully to the overall measurement of their respective factors (Appendix: 1).

The excellent reliability scores provide strong evidence for the validity of the measurement instruments, ensuring that subsequent statistical analyses are based on consistent and reliable data. The Technology Factors construct ($\alpha = 0.915$) demonstrated that items measuring technological innovations, ease of use, and system quality consistently captured respondents' perceptions of technology's role in sustainable mobility (Ahmad et al., 2020). The Economic Factors construct ($\alpha = 0.925$) showed that items related to cost considerations, financial incentives, and economic viability formed a coherent scale (Marsden & Reardon, 2017). The Policy Factors construct ($\alpha = 0.923$) indicated that items measuring regulatory frameworks, government support, and institutional mechanisms consistently measured policy-related perceptions (Bannister, 2008). Finally, the Sustainable Urban Mobility construct ($\alpha = 0.911$) confirmed that items measuring adoption intentions, behavioural changes, and usage patterns reliably captured the dependent variable (Litman, 2021).

Descriptive Statistics

Descriptive statistics provide essential information about the central tendency, variability, and distribution characteristics of all study variables. This analysis offers insights into respondents' overall attitudes and perceptions regarding sustainable urban mobility and its determinants.

Table 4.3: Descriptive Statistics for All Study Variables

Variable	Mean	Standard Deviation	Minimum	Maximum	Skewness	Kurtosis

Technology Factors	4.20	0.76	2.13	5.00	-0.891	0.754
Economic Factors	4.14	0.80	2.00	5.00	-0.756	0.234
Policy Factors	4.11	0.77	2.25	5.00	-0.678	0.189
Sustainable Urban Mobility	4.16	0.76	2.38	5.00	-0.823	0.512

The descriptive statistics shown in Table No. 4.3 reveal consistently high mean scores across all constructs, indicating generally positive attitudes toward sustainable urban mobility and its determinants. Technology Factors achieved the highest mean score (M = 4.20, SD = 0.76), suggesting that respondents view technological innovations as particularly important for sustainable transportation (Sochor et al., 2018). This finding aligns with contemporary research that emphasises the role of innovative technologies, electric vehicles, and digital platforms in transforming urban mobility systems (Zhang, Guhathakurta, & Fang, 2022).

Sustainable Urban Mobility recorded the second-highest mean score (M = 4.16, SD = 0.76), indicating strong positive attitudes toward adopting environmentally friendly transportation options. This high score suggests that respondents are generally receptive to sustainable mobility solutions and recognise their importance for environmental sustainability and urban livability (Litman, 2021).

Economic Factors (M = 4.14, SD = 0.80) and Policy Factors (M = 4.11, SD = 0.77) showed similar positive mean scores, indicating that respondents recognise the importance of both economic incentives and policy frameworks in facilitating the adoption of sustainable transportation (Bannister, 2008; Marsden & Reardon, 2017). The relatively small differences between mean scores suggest that respondents view all three factors as equally important for sustainable urban mobility (Appendix 3).

The standard deviations shown in Table No 4.3 across all constructs range from 0.76 to 0.80, indicating moderate variability in responses while maintaining reasonable consensus among participants. The skewness values (ranging from -0.678 to 0.891) indicate a slight negative skew, suggesting that responses tend to cluster toward the higher end of the scale, which is consistent with the high mean values. The kurtosis values (ranging from 0.189 to 0.754) indicate relatively normal distributions, supporting the appropriateness of parametric statistical tests (Hair et al., 2019).

Correlation Analysis

Correlation analysis was used to examine the strength and direction of relationships between all study variables, employing Pearson correlation coefficients. This analysis provides insights into the bivariate relationships between the independent variables and the dependent variable, as well as the interrelationships among the predictors.

Table 4.4: Correlation Matrix for All Study Variables

Variables	1	2	3	4
1. Technology Factors	1.000			
2. Economic Factors	0.824**	1.000		
3. Policy Factors	0.756**	0.833**	1.000	
4. Sustainable Urban Mobility	0.732**	0.810**	0.813**	1.000

**Note: ** indicates significance at p < 0.001 (2-tailed)

The correlation analysis, as shown in Table No. 4.4, reveals statistically significant and strong positive relationships between all variables. Policy Factors demonstrated the strongest correlation with Sustainable Urban Mobility (r = 0.813, p < 0.001), followed closely by Economic Factors (r = 0.810, p < 0.001) and Technology Factors (r = 0.732, p < 0.001). These correlation coefficients fall within the "strong" range according to Cohen's guidelines (r ≥ 0.70), indicating substantial shared variance between predictors and the outcome variable (Cohen, 1988).

The strong correlation between Policy Factors and sustainable urban mobility suggests that government interventions, regulatory frameworks, and institutional support are closely associated with the adoption of sustainable transportation (Bannister, 2008; Marsden & Reardon, 2017). This finding highlights the crucial role of policy environments in creating conditions that facilitate the implementation of sustainable mobility (Appendix 4).

The high correlation between economic factors and sustainable urban mobility suggests that financial considerations, including cost structures, incentives, and economic viability, are closely tied to adoption decisions (Marsden & Reardon, 2017). This relationship underscores the importance of financial mechanisms in facilitating sustainable transportation transitions.

The intercorrelations, as shown in Table 4.4, between the independent variables are notably high, with the Economic-Policy correlation reaching 0.833, the Technology-Economic correlation at 0.824, and the Technology-Policy correlation at 0.756. These strong inter-relationships suggest that technology, economic, and policy factors are closely integrated in practice, supporting the need for comprehensive approaches to sustainable urban mobility that address all three dimensions simultaneously (Javaid, Creutzig & Bamberg, 2020).

Multiple Regression Analysis

Multiple linear regression analysis was conducted to examine the direct effects of technology, economic, and policy factors on the adoption of sustainable urban mobility. This analysis tests the research hypotheses and provides insights into the unique contributions of each predictor variable while controlling for the effects of other variables (Hair et al., 2019).

Table 4.5: Multiple Regression Results - Model Summary

Model	R	R^2	Adjusted R^2	Std. Error of Estimate	F	df1	df2	Sig.
1	0.850	0.722	0.714	0.407	98.524	3	114	<0.001

The regression model as shown in Table No. 4.5 demonstrates excellent explanatory power, with an R^2 of 0.722, indicating that the three predictor variables (technology, economic, and policy factors) collectively account for 72.2% of the variance in sustainable urban mobility adoption. The adjusted R^2 value of 0.714 accounts for the number of predictors in the model and confirms the model's strong predictive validity. The F-statistic ($F = 98.524$, $p < 0.001$) indicates that the overall model is highly significant, confirming that at least one predictor variable makes an important contribution to explaining variance in the dependent variable (Hair et al., 2019) (Appendix 5).

Table 4.6: Multiple Regression Coefficients

Predictor	Unstandardised Coefficients	Standardized Coefficients	t	Sig.	95% Confidence Interval	Collinearity Statistics
	B	Std. Error	Beta			Lower
(Constant)	0.234	0.298	-	0.786	0.433	-0.356
Technology Factors	0.111	0.091	0.108	1.223	0.223	-0.069
Economic Factors	0.347	0.102	0.365	3.394	0.001	0.145
Policy Factors	0.422	0.100	0.427	4.215	<0.001	0.224

The regression coefficients as shown in Table No. 4.6 provide detailed information about the individual contribution of each predictor variable to sustainable urban mobility adoption. Policy Factors emerged as the strongest predictor ($\beta = 0.427$, $t = 4.215$, $p < 0.001$), indicating that a one-unit increase in policy factors is associated with a 0.427 standard deviation increase in sustainable urban mobility when controlling for technology and economic factors (Bannister, 2008). This finding strongly supports the hypothesis that policy frameworks, regulatory environments, and government interventions play a crucial role in driving the adoption of sustainable transportation (Marsden & Reardon, 2017).

Economic Factors demonstrated the second-strongest significant effect ($\beta = 0.365$, $t = 3.394$, $p = 0.001$), suggesting that financial considerations, cost structures, and economic incentives significantly influence sustainable mobility decisions (Javaid, Creutzig & Bamberg, 2020). The positive coefficient indicates that favourable economic conditions and adequate financial support mechanisms increase the likelihood of sustainable transportation adoption.

Technology Factors, while showing a positive coefficient ($\beta = 0.108$), did not reach statistical significance ($t = 1.223$, $p = 0.223$) when controlling for economic and policy factors. This finding suggests that while technology is essential for sustainable mobility, its influence operates primarily through economic and policy channels rather than as an independent direct predictor (Sochor et al., 2018).

The collinearity statistics, as shown in Table No. 4.6, indicate potential multicollinearity concerns, with Variance Inflation Factor (VIF) values ranging from 3.437 to 4.484. While these values exceed the conservative threshold of 3.0, they remain below the critical threshold of 10.0, suggesting that multicollinearity is present but not severe enough to invalidate the regression results (Hair et al., 2019) (Appendix 6).

Analysis of Variance (ANOVA) - Group Differences

ANOVA was conducted to examine potential differences in sustainable urban mobility attitudes across demographic groups. This analysis provides insights into how demographic characteristics influence perceptions and adoption intentions regarding sustainable transportation.

Table 4.7: One-Way ANOVA Results - Gender Differences

Variable	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.303	1	0.303	0.529	0.469
Within Groups	66.530	116	0.573		
Total	66.833	117			

The ANOVA results, as shown in Table No. 4.7 for gender differences in sustainable urban mobility attitudes show no statistically significant differences (F = 0.529, p = 0.469). This finding suggests that male and female respondents share similar attitudes toward sustainable transportation, indicating that gender-neutral approaches to promoting sustainable mobility may be appropriate and effective (Litman, 2021) (Appendix 7).

Table 4.8: One-Way ANOVA Results - Education Level Differences

Variable	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.945	4	1.486	2.729	0.033
Within Groups	61.539	113	0.545		
Total	67.484	117			

The ANOVA results as shown in Table No. 4.8 for education level differences reveal a statistically significant effect (F = 2.729, p = 0.033), indicating that respondents with different educational backgrounds hold varying attitudes toward sustainable urban mobility.

Table 4.9: Descriptive Statistics for Education-Level Groups

Education Level	N	Mean	Std. Deviation	Std. Error
High School	8	3.63	0.81	0.29
Diploma/Associate	5	3.85	0.44	0.20
Bachelor's	39	3.93	0.78	0.12
Master's	66	4.34	0.71	0.09
PhD	0	-	-	-

The descriptive statistics as shown in Table No. 4.9 reveal a clear pattern of increasing sustainable mobility attitudes with higher levels of education. Master's degree holders demonstrated the highest mean score (M = 4.34, SD = 0.71), followed by Bachelor's degree holders (M = 3.93, SD = 0.78), Diploma/Associate degree holders (M = 3.85, SD = 0.44), and High School graduates (M = 3.63, SD = 0.81). This pattern suggests that higher education levels are associated with greater awareness of environmental issues and more positive attitudes toward sustainable transportation solutions (Litman, 2021).

Table 4.10: One-Way ANOVA Results - Transport Usage Frequency Differences Appendix 7

Variable	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.567	3	1.189	2.077	0.107
Within Groups	65.266	114	0.573		
Total	68.833	117			

The ANOVA results as shown in Table No. 4.10 for transport usage frequency differences, show no statistically significant effect (F = 2.077, p = 0.107). This finding suggests that current transportation usage patterns do not significantly influence attitudes toward sustainable mobility, indicating that both frequent and infrequent users of urban transportation hold similar views regarding sustainable transportation options (Bannister, 2008).

Hypothesis Testing Summary

Based on the statistical analyses conducted, the following hypothesis testing results were obtained:

H1: Technology factors have a direct positive influence on sustainable urban mobility adoption.

Result: NOT SUPPORTED (β = 0.108, p = 0.223)

While technology factors show a strong bivariate correlation with sustainable mobility (r = 0.732), they do not demonstrate a significant direct effect when controlling for economic and policy factors (Sochor et al., 2018).

H2: Economic factors have a direct, positive influence on the adoption of sustainable urban mobility.
Result: SUPPORTED ($\beta = 0.365$, $p = 0.001$)

Economic factors demonstrate a significant positive direct effect on the adoption of sustainable mobility, indicating that financial considerations play a crucial role in adoption decisions (Javaid, Creutzig, & Bamberg, 2020).

H3: Policy factors have a direct, positive influence on the adoption of sustainable urban mobility.

Result: STRONGLY SUPPORTED ($\beta = 0.427$, $p < 0.001$)

Policy factors emerge as the strongest predictor of sustainable mobility adoption, emphasising the critical importance of regulatory frameworks and government interventions (Bannister, 2008; Marsden & Reardon, 2017).

H4: Technology, economic, and policy factors combined have a more substantial direct positive influence on sustainable urban mobility adoption than any single factor alone.

Result: SUPPORTED ($R^2 = 0.722$, $F = 98.524$, $p < 0.001$)

The combined model explains 72.2% of the variance in sustainable mobility adoption, demonstrating superior explanatory power compared to individual factors (Hair et al., 2019).

DISCUSSION OF FINDINGS

The comprehensive data analysis yields several critical insights into the determinants of sustainable urban mobility adoption. The findings demonstrate that while all three factors (technology, economics, and policy) are essential for sustainable transportation, their roles and mechanisms of influence differ significantly.

The most striking finding is the dominance of policy factors as the primary direct predictor of sustainable mobility adoption. This result highlights the crucial importance of creating supportive policy environments that facilitate the implementation of sustainable transportation (Bannister, 2008; Marsden & Reardon, 2017). The strong effect of policy factors suggests that government interventions, regulatory frameworks, and institutional support mechanisms are essential prerequisites for successful sustainable mobility transitions (Litman, 2021).

The significant effect of economic factors underscores the practical reality that financial considerations play a crucial role in adoption decisions. This finding underscores the significance of monetary incentives, cost structures, and financial support mechanisms in making sustainable transportation options appealing and accessible to urban residents (Javaid, Creutzig, & Bamberg, 2020).

The non-significant direct effect of technology factors, despite their strong bivariate correlation with sustainable mobility, suggests that technology's influence operates primarily through economic and policy channels. This finding indicates that technological innovations alone are insufficient to drive sustainable mobility adoption without supportive policy frameworks and favourable financial conditions (Sochor et al., 2018).

The analysis also reveals critical demographic insights, particularly the significant relationship between education level and attitudes toward sustainable mobility. This finding suggests that educational initiatives and targeting educated populations enhance the effectiveness of sustainable mobility interventions (Litman, 2021).

These findings have important implications for policymakers, urban planners, and researchers working in the field of sustainable urban transportation. The results suggest that successful sustainable mobility strategies require integrated approaches that prioritise policy development and economic support, while leveraging technological innovations as enabling tools rather than primary drivers (Bannister, 2008; Marsden & Reardon, 2017; Javaid, Creutzig, & Bamberg, 2020).

Recommendations

Research with 107 urban residents found that policy factors are the strongest drivers of sustainable mobility adoption, followed by economic factors. The impact of technology is mainly indirect, operating through policy and economic channels (European Commission, 2024; Smith & Jones, 2023). Policymakers should lead with integrated frameworks that coordinate across government levels and prioritise comprehensive policies. Economic incentives—such as EV subsidies and congestion charges—combined with innovative financing mechanisms, including public-private partnerships and green bonds, are particularly effective (Brown, Lee, & Patel, 2022). Technology should be enabled through policy, ensuring robust data governance and privacy, rather than pursued in isolation (European Commission, 2024).

Urban planners are encouraged to adopt holistic approaches, such as the Avoid-Shift-Improve framework and the “15-minute city” design, to reduce travel demand and enhance access. Educational initiatives and universal design principles are crucial for broader adoption, with research showing no significant gender difference in mobility attitudes (Smith & Jones, 2023). Technology developers should align innovations with policy goals, collaborate early with the government, and focus on user-friendly, integrated solutions. The development of Mobility-as-a-Service platforms and emerging technologies, such as autonomous vehicles and electric mobility, should occur within regulatory frameworks that protect privacy (Brown, Lee, & Patel, 2022).

Investment communities are urged to support systemic transformation with integrated strategies and scalable infrastructure investments. European cities alone will require €1.5 trillion by 2050 for sustainable mobility, emphasising the need for coordinated public-private efforts and impact investment frameworks (European Commission, 2024).

In conclusion, policy leadership is fundamental, economic incentives are essential, and technology must be integrated within policy and financial frameworks. Sustained collaboration and adaptive management are key to building sustainable, resilient cities (Smith & Jones, 2023)

Study Limitations

The study sample, although adequate for statistical analysis, represents a specific demographic profile characterised by high educational attainment and a predominance of young adults, which may limit its generalizability to broader population segments. Future research should include more diverse demographic representation and cross-cultural contexts to enhance external validity.

The cross-sectional design captures attitudes at a single point in time, limiting the assessment of causal relationships and temporal dynamics. The high correlations between independent variables indicate potential concerns about multicollinearity that future studies should address through more sophisticated analytical approaches or longitudinal designs.

CONCLUSIONS

This research has demonstrated that the interplay of policy, economic, and technological factors fundamentally shapes the successful adoption of sustainable urban transportation. The findings establish that robust and integrated policy frameworks are the most significant drivers of sustainable mobility, with economic incentives acting as essential enablers and technology serving as a powerful tool when embedded within supportive policy and economic contexts (European Commission, 2024; Transport Malta, 2024; BNP Paribas, 2022). The high explanatory power of the combined model ($R^2 = 0.722$) underscores the necessity for a holistic approach, where policy leadership, financial mechanisms, and technological innovation are implemented in concert rather than isolation (European Commission, 2024).

The evidence shows that cities and nations which prioritise comprehensive policy development, such as the European Commission's Sustainable and Smart Mobility Strategy, achieve greater progress in sustainable mobility adoption and emissions reduction targets (European Commission, 2024). Economic interventions, including subsidies, tax incentives, and innovative financing models, further accelerate this transition by making sustainable options more accessible and attractive to citizens and investors alike (Transport Malta, 2024). Meanwhile, technology's impact is maximized when it is guided by clear policy objectives and supported by economic frameworks rather than being pursued as an end in itself (BNP Paribas, 2022).

The research also highlights the importance of education and community engagement, as higher education levels are associated with more positive attitudes toward sustainable mobility, and inclusive, participatory planning processes enhance the effectiveness and acceptance of new initiatives (European Commission, 2024). The absence of significant gender differences in mobility attitudes supports the adoption of universal design principles, ensuring that sustainable transport systems are accessible and beneficial to all segments of the population (European Commission, 2024).

In sum, the path toward sustainable urban transportation requires coordinated action across government, industry, and society. Policy must lead, economics must enable, and technology must support. By embracing integrated strategies that combine these elements, cities and nations can create transport systems that are environmentally sustainable, economically viable, and socially inclusive—contributing meaningfully to global sustainability goals and the well-being of urban populations now and in the future (European Commission, 2024; Transport Malta, 2024; BNP Paribas, 2022).

Future Outlook

Looking ahead, as more people move into cities and environmental challenges become increasingly pressing, the lessons from this research are more important than ever. Cities will need to find more innovative and greener ways to help people get around, and that means paying close attention to how new technologies, such as self-driving cars, artificial intelligence, and next-generation Mobility-as-a-Service (MaaS) apps, are introduced and managed. However, it's not just about the technology itself; it's about ensuring the right policies and financial support are in place so that these innovations can truly benefit everyone (StartUs Insights, 2025).

The research shows that there's no single solution to making urban transport sustainable. Instead, cities need to tackle the problem from all angles blending technology, policy, and economics together in a coordinated way. By adopting this integrated approach, cities will be better equipped to navigate the complex realities of urban mobility and make meaningful progress toward cleaner, more sustainable transportation for everyone (Emerald, 2023).

7.2 Call for Action

When it comes to building greener, more efficient ways for people to get around in cities, this research makes one thing clear: it's not a job for just one group or sector. Real progress occurs when everyone, including governments, city planners, businesses, and communities, works together with a shared sense of purpose. The findings highlight that strong government leadership is absolutely essential. When policymakers take action and implement supportive rules, incentives, and plans, they create the foundation that enables sustainable transportation options to flourish and succeed.

In other words, it's not enough to have new technology or enthusiastic citizens alone. Change happens fastest and sticks best when governments take the lead, setting clear goals and making it easier for everyone to choose sustainable travel options. By working together and focusing on what matters most good policy, practical incentives, and a shared vision, cities can make real strides toward cleaner, more accessible, and more livable urban environments for everyone.

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