

Frugal Innovation and Sustainable Mobility: Low-Tech Pathways Toward a Sober and Equitable Future.

Auteur 1 : TACHFINE Youssef.

Auteur 2 : ACHRIH Lamia.

TACHFINE YOUSSEF, (Professor – Researcher)

IBN ZOHR University / Faculty of Legal, Economic and Social Sciences

Social Organization Management and Territorial Economics Research Unit (ETMOSET)

ACHRIH LAMIA, (0009-0009-0132-9899, PhD Student)

IBN ZOHR University / Faculty of Legal, Economic and Social Sciences

Social Organization Management and Territorial Economics Research Unit (ETMOSET)

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Abstract

Achieving sustainable mobility has become a critical challenge for modern cities facing environmental, economic, and social pressures. This research investigates how frugal innovation contributes to the acceptability of sustainable mobility solutions through three key mediating mechanisms: technological appropriation, social innovation, and urban resilience. Empirical data were collected through a quantitative survey conducted among 270 respondents in the Greater Agadir area and analyzed using linear regression and mediation models. The results indicate that frugal innovation significantly enhances both technological appropriation and social innovation, whereas its direct contribution to urban resilience remains relatively weak. Nonetheless, the acceptability of sustainable mobility is largely driven by indirect effects operating through the three mediators, confirming a full mediation structure. Moreover, multiple regression analysis reveals that technological appropriation emerges as the most influential determinant of acceptability. These findings underline the importance of integrated strategies that combine technological adaptation, community involvement, and resilience-building to support inclusive and sustainable urban mobility policies.

Keywords: frugal innovation, sustainable mobility, Greater Agadir.

Introduction

The transition toward sustainable mobility models has become a major challenge for contemporary cities, which are increasingly confronted with environmental issues (reduction of CO₂ emissions and air pollution), economic constraints (control of transportation costs), and social concerns (accessibility and inclusion). Within this context, frugal innovation emerges as a promising approach by offering simple, affordable, and user-centered solutions while minimizing the use of resources. Beyond its technical dimension, frugal innovation also encourages the development of collective initiatives and innovative social practices, thereby contributing to the strengthening of urban systems' resilience in the face of crises.

However, the acceptability of sustainable mobility remains a crucial issue for the successful implementation of such solutions. It depends on several interrelated factors, notably individuals' ability to appropriate the proposed solutions, the social dynamics they generate, and their contribution to the robustness and adaptability of urban systems. Despite the growing interest in frugal and low-tech mobility solutions, the mechanisms through which frugal innovation influences citizens' acceptance of sustainable mobility remain insufficiently explored, particularly in the context of cities in the Global South.

The objective of this study is therefore to analyze how frugal innovation contributes to the acceptability of sustainable mobility by examining the mediating roles of technological appropriation, social innovation, and urban resilience. More specifically, this research seeks to assess the effect of frugal innovation on users' capacity to appropriate mobility solutions, its role in fostering social innovation initiatives, and its contribution to strengthening urban resilience, as well as the combined influence of these dimensions on the acceptability of sustainable mobility.

To address this question, a quantitative survey was conducted among 270 urban transport users in the Greater Agadir area. The collected data were analyzed using descriptive statistics, regression analyses, and mediation models to test the proposed hypotheses and to identify the key drivers that facilitate the adoption and legitimation of sustainable mobility solutions.

This article is organized around a progressive analytical logic. It begins with a critical review of the literature on frugal innovation, sustainable mobility, and low-tech approaches. It then develops the theoretical foundations of the study before presenting the conceptual framework and the research hypotheses. The methodological design and data analysis strategy are subsequently described, followed by a detailed discussion of the empirical results. The article concludes by synthesizing the main findings and outlining their theoretical contributions and policy implications for sustainable mobility.

1. Literature review

1.1. Frugal innovation

Frugal innovation refers to the ability to design simple, robust, and cost-effective solutions by relying on locally available resources and aiming for maximum utility under conditions of strong constraints. According to Radjou, Prabhu, and Ahuja (2012), it consists of “doing more with less,” that is, generating significant social and economic value while minimizing the use of resources such as energy, capital, or time. From a more structured perspective, Weyrauch and Herstatt (2016) define frugal innovation as an approach that significantly reduces the total cost of ownership while maintaining an acceptable level of performance. From a socio-economic standpoint, Bound and Thornton (2012) emphasize that this form of innovation enables the development of accessible, affordable, and need-oriented solutions for disadvantaged populations. Far from being a mere fallback alternative, frugal innovation is grounded in a logic of efficiency and relevance, particularly suited to the realities of Global South countries and rural areas. It challenges the dominant model of technology-intensive innovation by valuing collective intelligence, informal practices, and local experimentation.

1.2. Sustainable Mobility

At the same time, the concept of sustainable mobility has emerged as a strategic framework for rethinking transport systems from the perspective of environmental sustainability, social equity, and economic efficiency. According to Banister (2008), the sustainable mobility paradigm seeks to reduce the need for travel, promote modal shift toward more sustainable modes, and improve the environmental and social performance of transport systems. Complementarily, the Organisation for Economic Co-operation and Development (OECD, 2002) defines a sustainable transport system as one that meets individuals’ fundamental access and development needs while limiting emissions, waste, and the consumption of non-renewable resources. From an intergenerational perspective, the European Conference of Ministers of Transport (ECMT, 2004) emphasizes that sustainable mobility aims to satisfy the mobility needs of present generations without compromising the ability of future generations to meet their own. This concept thus promotes an integrated approach to mobility, combining spatial justice, energy sobriety, and inclusive accessibility.

1.3. Technological Sobriety and Low-Tech Approaches

Building on reflections on frugal innovation, the concept of low-tech has emerged as a coherent approach aligned with the objectives of strong sustainability and social justice. Low-tech technologies are characterized by functional simplicity, low resource consumption, repairability, and long-term durability. According to Philippe Bihouix (2014), low-tech solutions represent a realistic response to the deadlock of unlimited technological progress by offering sober, robust

devices adapted to the essential needs of societies. The author criticizes the illusion of an ecological transition based solely on “green” high-tech solutions and advocates a redefinition of innovation grounded in sobriety, relocalization, and citizen control of technologies. In the field of mobility, low-tech approaches enable the development of concrete alternatives such as bicycles made from recycled materials, artisanal carpooling systems, and lightweight vehicles optimized for local use. These initiatives, often driven by collectives, associations, or micro-entrepreneurs, reconnect innovation with its territory of use and promote community autonomy. They thus embody a form of technological sobriety understood not as regression, but as a refocusing on essential needs, breaking with the logic of technological sophistication and planned obsolescence (Bihouix, 2014; Plepys, 2002). This orientation aligns with calls for a just, inclusive, and ecologically sustainable transition based on technological choices compatible with planetary boundaries.

2. Theoretical Framework

2.1. Theory of Technological Appropriation

The theory of technological appropriation highlights the active role of users in adapting or reinterpreting technologies according to their specific contexts. Applied to frugal mobility solutions, it makes it possible to understand how users appropriate low-tech devices based on their real needs (Akrich, 1998; De Vaujany, 2006). This perspective sheds light on local dynamics of use transformation in constrained environments, where technologies are often reshaped through practical experimentation and everyday practices.

2.2. Theory of Urban Resilience

Urban resilience refers to the ability of territories to adapt to crises while ensuring the continuity of their essential functions. Frugal mobility solutions, due to their simplicity and adaptability, contribute to strengthening this resilience, particularly in times of disruption (Meerow, Newell & Stults, 2016). They help maintain accessibility and mobility even under conditions of limited resources, thereby reinforcing the robustness of urban transport systems.

2.3. Sustainable Mobility Paradigm

The sustainable mobility paradigm proposes a rethinking of transport systems based on social, environmental, and economic criteria. It promotes sobriety, equity of access, and modal shift toward more sustainable transport solutions (Banister, 2008). Frugal innovations fit within this paradigm by providing accessible alternatives to dominant technology-intensive models, thus supporting more inclusive and environmentally responsible mobility systems.

2.4. Theory of Social Innovation

Social innovation refers to collective initiatives aimed at addressing needs that are not sufficiently covered by market mechanisms or institutional arrangements. It is particularly relevant for analyzing low-tech mobility practices driven by local actors within a participatory logic (Moulaert

et al., 2013). These solutions, often co-constructed by communities, promote territorial inclusion and social justice by strengthening citizens' involvement in the development of sustainable mobility alternatives.

3. Conceptual Framework

3.1. The Conceptual Framework

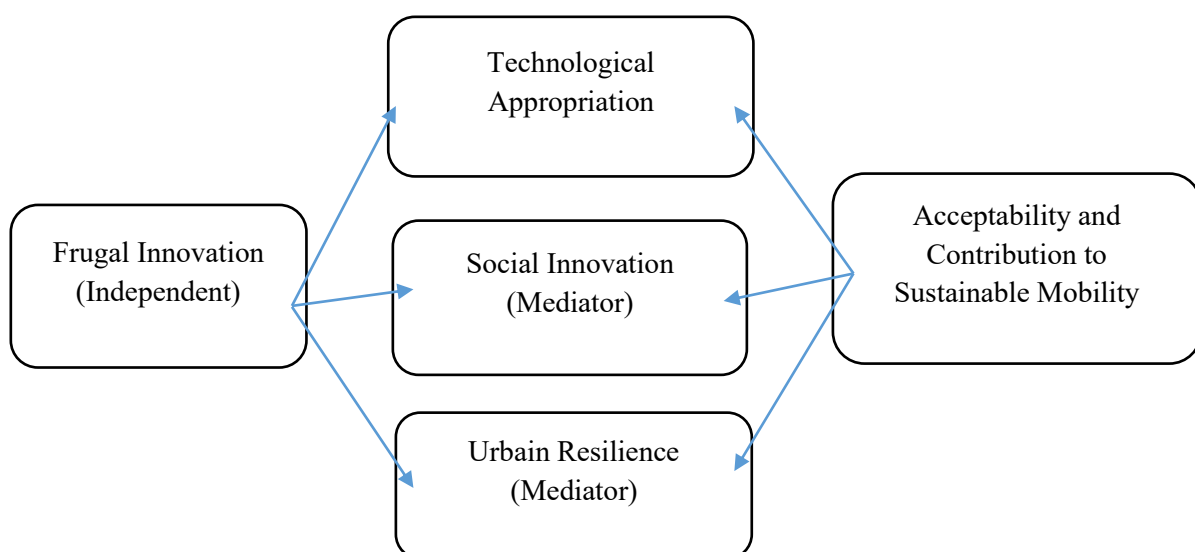
The proposed conceptual framework is built on three major theoretical pillars: technological appropriation, social innovation, and urban resilience, together with the sustainable mobility paradigm. This choice makes it possible to simplify and clarify the analysis while maintaining a robust and relevant theoretical foundation.

Tableau 1 : Study Variables

Variable Category	Variables	Main Theory
Independent Variable	Perceived Frugal Innovation	Technological Appropriation
Mediators	- Technological Appropriation (use, adaptation, tinkering) - Social Innovation & Urban Resilience (co-construction, continuity, robustness)	Technological Appropriation + Social Innovation & Urban Resilience
Dependent Variable	Acceptability & Contribution to Sustainable Mobility	Sustainable Mobility

Source : Author

Figure 1: Conceptual Framework



Source : Author

3.2. Research Hypotheses

Based on the proposed conceptual framework, four main hypotheses are formulated. They reflect the causal logic between frugal innovation, its mechanisms of appropriation and mediation, and the acceptability of sustainable mobility solutions.

Tableau 2: Research Hypotheses

Hypothesis	Tested Relationship
H1	Perceived frugal innovation positively influences users' technological appropriation.
H2	Frugal innovation stimulates the emergence of social innovation initiatives.
H3	Frugal innovation strengthens the urban resilience of mobility systems.
H4	Technological appropriation, social innovation, and urban resilience mediate the relationship between frugal innovation and the acceptability of sustainable mobility.
H5	The acceptability and contribution to sustainable mobility jointly depend on technological appropriation, social innovation, and urban resilience resulting from frugal innovation.

Source : Author

4. Research Methodology

This study adopts a quantitative research approach based on a questionnaire survey. The objective is to quantify perceptions, practices, and determinants of acceptance of frugal mobility solutions in the Greater Agadir area, to assess their potential contribution to sustainable and equitable mobility.

4.1. Methodological Approach

This research is grounded in a positivist epistemological positioning, which assumes that social phenomena related to mobility behaviors and perceptions can be observed, measured, and analyzed through empirical data. In line with this stance, the study adopts a hypothetico-deductive mode of reasoning, whereby theoretical assumptions derived from the literature on frugal innovation, technological appropriation, social innovation, and urban resilience are translated into testable hypotheses.

A quantitative approach was selected to empirically test the hypotheses derived from the conceptual framework and to measure the relationships between the variables (independent, mediating, and dependent). This approach makes it possible to:

- obtain results that can be generalized to the target population.
- quantify users' perceptions and attitudes toward frugal innovation.
- verify the statistical robustness of the conceptual model.

This methodological choice is consistent with prior research in the social sciences and transport economics, which frequently rely on questionnaire surveys and statistical analyses to validate explanatory models (Ajzen, 1991; Banister, 2008).

4.2. Sampling Design and Justification

The study is based on a survey sampling method using a questionnaire distributed among residents and transport users in the Greater Agadir area.

- **Target population:** citizens who use (or potentially use) public transport and frugal mobility solutions.
- **Inclusion criteria:** diversity in socio-economic profiles, age, gender, urban/peri-urban location, and frequency of public transport use.
- **Sample size:** for quantitative studies, methodological guidelines recommend a minimum of 5 to 10 respondents per questionnaire item (Hair et al., 2010). In this study, a sample size ranging from 250 to 300 respondents was considered appropriate to ensure statistical reliability and allow for multivariate analyses.

4.3. Data Processing and Analysis

Data were analyzed using SPSS (Statistical Package for the Social Sciences). The following steps were carried out:

- data cleaning and preparation (questionnaire verification, removal of incomplete responses, coding).
- descriptive analysis (means, frequencies, standard deviations).
- reliability analysis (Cronbach's alpha).
- exploratory factor analysis (EFA, principal component analysis with Varimax rotation).
- multiple regression analyses to test the conceptual model.
- hypothesis testing (correlations, ANOVA, mediation and moderation analyses using the Baron & Kenny approach, 1986, or Hayes' PROCESS macro).

This protocol allows the transformation of collected data into robust empirical results to confirm or reject the proposed hypotheses.

4.4. Final Sample after Data Screening

Out of the 300 collected questionnaires, two filtering criteria were applied: residence within the Greater Agadir area; and at least occasional use of a public, shared, or frugal transport mode (bus, shared taxi, walking, cycling, carpooling).

A total of 270 valid responses were retained for statistical analysis, while 30 questionnaires (10%) were excluded because they did not meet the inclusion criteria. This procedure ensures the representativeness of the sample and guarantees methodological transparency.

5. Results and Discussion

5.1. Description of the Sample

Tableau 3 : Socio-Demographic Characteristics of the Sample (N = 270)

Variable	Valid N	Dominant Category (Mode)	Standard Deviation	Interpretation
Residence in Greater Agadir	300	Yes (100%)	0.49	All respondents reside in Greater Agadir (inclusion criterion).
Occasional use of a public/shared/low-tech transport mode	300	Yes (100%)	0.50	All respondents use at least occasionally a collective or frugal transport mode (inclusion criterion).
Age	270	Category 2 (young adults)	1.10	Majority of respondents are young adults (25–34 years).
Gender	270	2 (Female majority)	0.49	The sample is slightly feminized.
Employment status	270	5 (Employees/self-employed)	1.72	Diverse distribution with predominance of economically active individuals.
Neighborhood / area of residence	270	2 (Urban)	1.73	Majority of respondents live in urban areas.
Ownership of a personal car	270	1 (No)	0.49	Most respondents do not own a personal vehicle.

Source: SPSS

Out of the 300 questionnaires collected, 270 were retained after applying the inclusion criteria. The sample is mainly composed of young adults (mode = Category 2, corresponding to the 25–34 age group), with a slight predominance of female respondents.

The professional status of the participants is diverse, although the category of employees/self-employed individuals is dominant (mode = 5). Most respondents live in urban neighborhoods of Greater Agadir and do not own a personal vehicle, which accurately reflects the target population of the study, namely potential users of collective and frugal mobility solutions.

Tableau 4: Descriptive Statistics of the Study Variables (N = 270)

Variable	N	Min	Max	Mean	Standard Deviation
Acceptability of Sustainable Mobility (ACC)	270	1.00	5.00	2.99	1.31
Frugal Innovation (FRU)	270	1.00	5.00	2.99	1.27
Technological Appropriation (TEC)	270	1.00	5.00	3.01	1.30
Social Innovation (SOC)	270	1.00	5.00	3.00	1.27
Urban Resilience (RES)	270	1.00	5.00	3.01	1.30

Source: SPSS

The descriptive results indicate that the five studied dimensions are positioned around the average level ($\approx 3/5$). Technological appropriation ($M = 3.01$) and urban resilience ($M = 3.01$) record the highest mean scores, reflecting a relatively positive perception of the impact of frugal solutions on users' capacity for adaptation and adoption. In contrast, social innovation ($M = 2.99$) appears less developed, indicating a still limited level of collective mobilization. The standard deviations, ranging between 1.26 and 1.31, reveal a notable dispersion of responses, suggesting a diversity of opinions among respondents.

5.2. Reliability and Validity of the Scales

5.2.1. Reliability

Tableau 5 : Internal Reliability of the Scales (Cronbach's Alpha)

Dimension	Number of Items	Cronbach's Alpha (α)	Interpretation
Frugal Innovation	6	0.953	Excellent reliability
Technological Appropriation	6	0.961	Excellent reliability
Social Innovation	6	0.956	Excellent reliability
Urban Resilience	6	0.957	Excellent reliability
Acceptability of Sustainable Mobility	8	0.974	Excellent reliability

Source: SPSS

The reliability test results show that all scales exhibit very high Cronbach's alpha coefficients (ranging between 0.95 and 0.97), which are well above the recommended threshold of 0.70. This indicates an excellent internal consistency of the items used to measure each dimension. Inter-item

correlations are also high (above 0.74), confirming the robustness of the scales and their suitability for statistical analysis.

5.2.2. Validity of the Scales

Tableau 6 : Results of the Exploratory Factor Analysis (EFA)

Dimension	KMO	Bartlett's Test (χ^2 , df, p)	Explained Variance (%)	Interpretation
Frugal Innovation	0.938	$\chi^2 = 1563.899$; df = 15; p < 0.001	77.23%	Very good factorial validity
Technological Appropriation	0.942	$\chi^2 = 1745.937$; df = 15; p < 0.001	80.32%	Excellent factorial validity
Social Innovation	0.943	$\chi^2 = 1621.475$; df = 15; p < 0.001	78.34%	Very good factorial validity
Urban Resilience	0.933	$\chi^2 = 1662.855$; df = 15; p < 0.001	77.90%	Very good factorial validity
Acceptability	0.964	$\chi^2 = 2751.528$; df = 28; p < 0.001	81.01%	Excellent factorial validity

Source: SPSS

The exploratory factor analysis (EFA) confirmed the construct validity of the measurement scales used in this study. The KMO index ranges between 0.93 and 0.96, indicating an excellent adequacy of the sample for factor analysis. Bartlett's test of sphericity is highly significant (p < 0.001) for all dimensions, which confirms the relevance of conducting the EFA. Finally, the variance explained by each single factor ranges between 77% and 81%, reflecting a strong capacity of the items to accurately represent their respective dimensions.

5.3. Correlations Between Variables

Tableau 7 : Pearson Correlations Between the Main Variables (N = 270)

Variables	Acceptability (acc_scor)	Frugal Innovation (frug_scor)	Technological Appropriation (tech_scor)	Social Innovation (socil_scor)	Urban Resilience (resil_scor)
Acceptability (acc_scor)	1	0.228**	0.542**	0.419**	0.319**
Frugal Innovation (frug_scor)	0.228**	1	0.356**	0.375**	0.288**

Technological Appropriation (tech_scor)	0.542**	0.356**	1	0.342**	0.265**
Social Innovation (socil_scor)	0.419**	0.375**	0.342**	1	0.276**
Urban Resilience (resil_scor)	0.319**	0.288**	0.265**	0.276**	1

**p < 0.01 (two-tailed correlation significance)

Source: SPSS

The Pearson correlation analysis reveals that all relationships between the variables are positive and statistically significant at the 1% level. Technological appropriation shows the strongest correlation with acceptability ($r = 0.542$), suggesting that the adoption of frugal solutions constitutes a major determinant of the acceptability of sustainable mobility. Frugal innovation is positively associated with social innovation ($r = 0.375$) and urban resilience ($r = 0.288$), confirming its role in fostering collective dynamics and enhancing the robustness of transport systems. The moderate correlations between social innovation and acceptability ($r = 0.419$), as well as between social innovation and urban resilience ($r = 0.276$), also highlight the importance of collective dynamics in anchoring sustainable mobility.

5.4. Hypothesis Testing and Regression Analyses

5.4.1. Hypothesis 1:

Hypothesis H1 states that frugal innovation positively influences users' technological appropriation. To test this hypothesis, a simple linear regression was conducted, in which the independent variable is frugal innovation (frug_scor) and the dependent variable is technological appropriation (tech_scor).

Tableau 8 : Results of the Simple Linear Regression (H1)

Model	R	R ²	Adjusted R ²	F	Sig.
H1: frug_scor → tech_scor	0.356	0.127	0.123	38.884	0.000

Dependent Variable: Technological Appropriation (tech_scor)

Independent Variable: Frugal Innovation (frug_scor)

Source: SPSS

Tableau 9 : Regression Coefficients for Hypothesis H1

Variable	Unstandardized B	Standard Error	Standardized Beta (β)	t (Sig.)
Constant	1.911	0.191	–	10.012 (p < 0.001)
Frugal Innovation (frug_scor)	0.366	0.059	0.356	6.236 (p < 0.001)

Dependent Variable: Technological Appropriation (tech_scor)

Independent Variable: Frugal Innovation (frug_scor)

Source: SPSS

The results indicate that frugal innovation has a positive and statistically significant effect on technological appropriation ($\beta = 0.356$; $t = 6.236$; $p < 0.001$). The model is globally significant ($F = 38.884$; $p < 0.001$) and explains approximately 12.7% of the variance in technological appropriation ($R^2 = 0.127$). These findings confirm Hypothesis H1, showing that frugal innovation effectively promotes users' technological appropriation.

5.4.2. Hypothesis 2 :

Hypothesis H2 states that frugal innovation stimulates the emergence of social innovation initiatives. To test this hypothesis, a simple linear regression was conducted, with frugal innovation (frug_scor) as the independent variable and social innovation (soc_scor) as the dependent variable.

Tableau 10 : Results of the Simple Linear Regression Analysis (H2)

Model	R	R ²	Adjusted R ²	F	Sig.
H2: frug_scor → soc_scor	0.375	0.140	0.137	43.773	0.000

Dependent Variable: Social Innovation (soc_scor)

Independent Variable: Frugal Innovation (frug_scor)

Source: SPSS

Tableau 11: Regression Coefficients for Hypothesis H2

Variable	Unstandardized B	Standard Error	Standardized Beta (β)	t (Sig.)
Constant	1.869	0.185	–	10.086 (p < 0.001)
Frugal Innovation (frug_scor)	0.377	0.057	0.375	6.616 (p < 0.001)

Dependent Variable: Social Innovation (soc_scor)

Independent Variable: Frugal Innovation (frug_scor)

Source: SPSS

The results show that frugal innovation has a positive and statistically significant effect on social innovation ($\beta = 0.375$; $t = 6.616$; $p < 0.001$). The model is globally significant ($F = 43.773$; $p <$

0.001) and explains approximately 14% of the variance in social innovation ($R^2 = 0.140$). These findings confirm Hypothesis H2, indicating that frugal innovation effectively stimulates the emergence of social innovation initiatives.

5.4.3. Hypothesis 3 :

Hypothesis H3 states that frugal innovation strengthens the urban resilience of mobility systems. To test this hypothesis, a simple linear regression was conducted, with frugal innovation (frug_scor) as the independent variable and urban resilience (resil_scor) as the dependent variable.

Tableau 12: Results of the Simple Linear Regression Analysis (H3)

Model	R	R ²	Adjusted R ²	F	Sig.
H3: frug_scor → resil_scor	0.288	0.083	0.080	24.315	0.000

Dependent Variable: Urban Resilience (resil_scor)

Independent Variable: Frugal Innovation (frug_scor)

Source: SPSS

Tableau 13 : Regression Coefficients for Hypothesis H3

Variable	Unstandardized B	Standard Error	Standardized Beta (β)	t (Sig.)
Constant	2.129	0.195	–	10.920 (p < 0.001)
Frugal Innovation (frug_scor)	0.296	0.060	0.288	4.931 (p < 0.001)

Dependent Variable: Urban Resilience (resil_scor)

Independent Variable: Frugal Innovation (frug_scor)

Source: SPSS

The results indicate that frugal innovation has a positive but relatively weak effect on urban resilience ($\beta = 0.288$; $t = 4.931$; $p < 0.001$). The model is globally significant ($F = 24.315$; $p < 0.001$) and explains approximately 8.3% of the variance in urban resilience ($R^2 = 0.083$).

Thus, Hypothesis H3 is confirmed, although the observed effect remains modest. These findings suggest that while frugal innovation contributes to urban resilience, it needs to be complemented by other levers (social, institutional, and technological) in order to further strengthen the robustness of mobility systems.

5.4.4. Hypothesis 4 (Mediation Analysis) :

The mediation analysis conducted using Hayes' PROCESS macro (Model 4, bootstrap with 5,000 samples) reveals that the direct effect of frugal innovation on the acceptability of sustainable mobility is not significant ($B = -0.069$; $p > 0.05$). This indicates that, when considered in isolation, frugal innovation does not directly lead to higher acceptability.

In contrast, all indirect effects through the mediating variables are statistically significant:

- via technological appropriation (B = 0.162; 95% CI [0.104; 0.228]);
- via social innovation (B = 0.098; 95% CI [0.052; 0.155]);
- via urban resilience (B = 0.045; 95% CI [0.010; 0.087]).

The total indirect effect is also significant (B = 0.305; 95% CI [0.223; 0.395]), confirming that these three mediators play a central role in the process.

These results therefore indicate a full mediation: frugal innovation influences acceptability only through technological appropriation, social innovation, and urban resilience. In other words, it is not frugal innovation per se that fosters citizens' adherence, but rather its capacity to be appropriated, to generate collective social dynamics, and to strengthen the resilience of mobility systems.

Tableau 14: Results of the Mediation Analysis (PROCESS – Model 4)

Tested Relationship	Coefficient (B)	Standard Error	t / z	p-value	95% CI [LLCI – ULCI]	Significance
Direct effect of FI → ACC	-0.069	0.057	-1.210	0.227	[-0.181 ; 0.043]	Not significant
Indirect effects via mediators						
→ Technological Appropriation (TEC)	0.1619	0.0315	–	–	[0.1038 ; 0.2278]	Significant
→ Social Innovation (SOC)	0.0980	0.0263	–	–	[0.0517 ; 0.1550]	Significant
→ Urban Resilience (RES)	0.0454	0.0195	–	–	[0.0105 ; 0.0874]	Significant
Total Indirect Effect (TEC + SOC + RES)	0.3053	0.0443	–	–	[0.2232 ; 0.3951]	Significant
Total Effect (Direct + Indirect)	≈ 0.2363	–	–	–	–	Significant (via mediators)

Independent Variable: Frugal Innovation (frug_scor)

Dependent Variable: Acceptability (acc_scor)

Mediators: Technological Appropriation (tech_scor), Social Innovation (soc_scor), Urban Resilience (res_scor)

Source: SPSS

5.4.5. Hypothesis 5

Hypothesis H5 states that technological appropriation, social innovation, and urban resilience positively influence the acceptability of sustainable mobility.

❖ Model Summary

- **R = 0.611**
- **R² = 0.373**, indicating that the model explains **37.3% of the variance in acceptability**.
- **F(3, 266) = 52.781, p < 0.001**, showing that the model is **globally statistically significant**.

❖ ANOVA

The regression is statistically significant (**p < 0.001**), which confirms that the predictors contribute significantly to explaining the acceptability of sustainable mobility.

Tableau 15: Predictor Coefficients for Hypothesis H5

Variable	Standardized Beta (β)	t-value	Sig.
Technological Appropriation	0.407	8.523	0.000
Social Innovation	0.235	4.461	0.000
Urban Resilience	0.141	2.745	0.006

Independent Variable: Frugal Innovation (frug_scor)

Dependent Variable: Acceptability (acc_scor)

Mediators: Technological Appropriation (tech_scor), Social Innovation (soc_scor), Urban Resilience (res_scor)

Source: SPSS

Technological appropriation has the strongest effect on the acceptability of sustainable mobility ($\beta = 0.407, p < 0.001$), confirming its central role in shaping users' acceptance. Social innovation also significantly influences acceptability ($\beta = 0.235, p < 0.001$), highlighting the importance of collective dynamics and participatory initiatives. Urban resilience contributes positively as well, although with a more moderate effect ($\beta = 0.141, p = 0.006$). Overall, these results validate Hypothesis H5, confirming that acceptability is jointly determined by technological, social, and resilience-related dimensions.

6. Synthesis of Results

Tableau 16: Summary of Hypothesis Testing Results

Hypothesis	Tested Relationship	Main Results	Conclusion
H1	Frugal Innovation → Technological Appropriation	$r = 0.356; R^2 = 0.127; \beta = 0.356; p < 0.001$	Validated
H2	Frugal Innovation → Social Innovation	$r = 0.375; R^2 = 0.140; \beta = 0.375; p < 0.001$	Validated

H3	Frugal Innovation → Urban Resilience	$r = 0.288$; $R^2 = 0.083$; $\beta = 0.288$; $p < 0.001$	Not validated (weak effect)
H4	Mediation (Technological Appropriation, Social Innovation, Urban Resilience) between Frugal Innovation and Acceptability	Direct effect not significant ($\beta = -0.069$; $p = 0.227$); Total indirect effect = 0.305 (95% CI [0.223; 0.395])	Validated (full mediation)
H5	Technological Appropriation + Social Innovation + Urban Resilience → Acceptability	$R^2 = 0.373$; $\beta_{\text{techno}} = 0.407$ ($p < 0.001$); $\beta_{\text{social}} = 0.235$ ($p < 0.001$); $\beta_{\text{resilience}} = 0.141$ ($p < 0.01$)	Validated

Source: SPSS

The results of the empirical tests provide a nuanced insight into the validity of the research hypotheses. First, frugal innovation exerts a positive and significant effect on technological appropriation (H1) and on social innovation (H2), thereby confirming its structuring role in the adoption of adapted and collaborative solutions. By contrast, its direct influence on urban resilience (H3) appears more limited, as the observed effect remains relatively weak despite being statistically significant, which leads to a partial rejection of this hypothesis.

About mediation (H4), the results show that technological appropriation, social innovation, and urban resilience play a major intermediary role: the direct effect of frugal innovation on acceptability is not significant, whereas the total indirect effect is significant, thus confirming the existence of full mediation. Finally, the multiple regression analysis (H5) confirms that acceptability is largely explained by the three dimensions, with the strongest contribution coming from technological appropriation, followed by social innovation and urban resilience.

Conclusion

This study largely confirms the proposed research hypotheses. The results show that frugal innovation has a positive impact on technological appropriation (H1) and social innovation (H2), while its direct effect on urban resilience remains limited (H3 not validated). However, the mediation analysis (H4) reveals that the acceptability of sustainable mobility relies on a significant indirect effect, mediated by technological appropriation, social innovation, and urban resilience, thereby validating the existence of full mediation. Finally, the multiple regression analysis (H5) highlights that technological appropriation, social innovation, and urban resilience constitute major and significant determinants of acceptability.

Overall, this research emphasizes that frugal innovation, although it does not directly influence all aspects of resilience, plays a structuring role by stimulating technological appropriation and social engagement, which in turn strengthen the acceptability of sustainable mobility solutions. These findings offer both **theoretical implications** (partial validation of the conceptual model) and **practical implications** (guidance for public policies toward accessible, inclusive, and resilient mobility solutions).

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