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Analysis of the direct and indirect impacts of consumer transition from fuel-powered motorcycles to electric bikes using path analysis

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Abstract
The world shift towards sustainability and environmental consciousness has spurred interest in alternative transportation modes, particularly electric bikes (e-bikes). E-bikes present a potential solution to urban transportation challenges by offering a cleaner, quieter, and more energy-efficient alternative to traditional fuel-powered bikes. This study explores the transition of consumer preferences from traditional fuel-powered bikes to electric bikes (e-bikes) using path analysis to examine both direct and indirect effects. In this study aims to estimate the functional relationship between dependent E-Bike Satisfaction with different independent variables like; Refilling, Eco-Friendly, Affordable Price, More Trendy, Comfort ability using path analysis.

Keywords: E- bikes, eco-friendly, correlation matrix, path analysis and multiple regression

Introduction
India is a country with the third-largest road network in the world. Road travel seemed to be a preferred choice in India with over 60% of the population used personal or shared vehicles to commute. With the current depletion of fossil fuels and its price hike, there is a need for another energy resource to run the vehicle. The automobile sector is considering Electric vehicles as a solution to the industry and environment in India. However, the current market penetration of EVs is relatively low despite governments implementing EV policies. In this analysis, respondents are satisfied with electric vehicles than fuel vehicles. Expenses, Mileage plays a vital role in satisfaction of vehicle. Whereas, amidst this increasing rate respondent prefer only fuel vehicle since it is satisfying the demand and also it is accessible for everyone and everything. But since the country walks towards sustainable development, people have awareness of using eco-friendly produces. So, there might be a period where fuel vehicles will be replaced by electric vehicles. In path analysis, the absence of such a correlation does not mean that the first variable is an unimportant predictor of the second variable, for it may still have an important indirect link. This is because a regression model can only deal with a single outcome variable. Path analysis, in contrast, may use several regression models simultaneously to examine all proposed relationships between predictor and outcome variables implied by the theoretical explanation. Consequently, path analysis is particularly useful when considering complex communication phenomena. Weinert, J. X., *et al*. (2007) [1] have studied, Lead-acid and lithium-ion batteries for the Chinese electric bike market and implications on future technology advancement. Dharmakeerthi, C. H., *et al*. (2014) [2] have studied Impact of electric vehicle fast charging on power system voltage stability. Dimitropoulos, A., *et al*. (2013) have studied Consumer valuation of changes in driving range: a meta-analysis. Transp. Res. Part Policy Pract. Liu, W., Chen, L. & Tian, J. (2016) [3] have studied Uncovering the evolution of lead in-use stocks in lead-acid batteries and the impact on future lead metabolism in China" Environmental Science and Technology. Sripad, S. and Viswanathan, V. (2017) [4]. have studied Performance metrics required of next-generation batteries to make a practical electric semi truck. ACS Energy Lett. Kerman, K., *et al*. (2017) [5] have studied Review practical challenges hindering the development of solid state Li ion batteries. J. Electrochem. Senthilkumar D and Sabarish P (2021) [6], have studied "Dairy Production: Predicting Analysis Using Auto Regressive Integrated Moving Average [ARIMA] Model, Tamil Nadu" Journal of Emerging Technologies and Innovative Research.

Senthilkumar D and Sabarish P (2022) [7] have studied Applications of Business Intelligence, Acceptance Sampling Plan and Prediction Analysis Based on Smart Watch.

Problem statement

While there is a general understanding that various factors contribute to the consumer's decision to switch from fuel-powered bikes to e-bikes, the nature of these factors and their interplay remains inadequately explored. Specifically, it is unclear how direct and indirect effects influence the transition decision, and how different variables such as cost, environmental concern, and technological perception interact with one another.

Research objectives

Identify Key the Factors to determine the primary factors influencing the decision of consumers to switch from fuel-powered bikes to e-bikes. Analyse Direct Effects: Examine the direct effects of each identified factor on the decision-making process. Examine Indirect Effects: Investigate how factors influence each other and contribute indirectly to the transition decision. Develop a Path Analysis Model: Construct a path analysis model to map out the relationships between factors and quantify both direct and indirect effects.

Expected outcomes

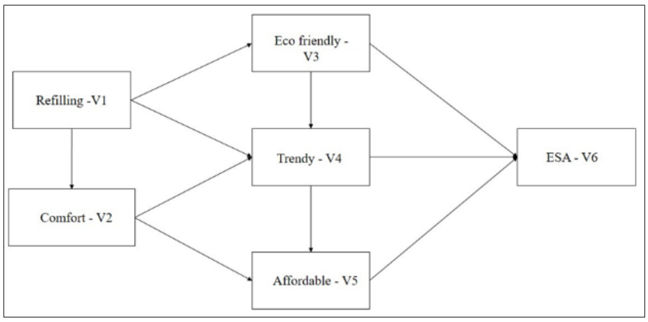
A detailed understanding of how different factors affect the decision to switch to e-bikes. Insights into the complex interplay of factors influencing consumer behaviour. Recommendations for stakeholders to support and accelerate the transition to more sustainable transportation options.

Methodology & Study limitations

Understanding the direct and indirect effects that drive the transition to e-bikes can provide valuable insights for manufacturers, policymakers, and marketers. It can help tailor strategies to encourage adoption, develop targeted incentives, and design effective communication campaigns to promote the environmental and economic benefits of e-bikes.

Path Diagram: Create a path diagram, which is a visual representation of the hypothesized relationships among variables. Variables are represented as nodes, and the relationships (or paths) between them are shown as arrows.

Path Analysis: Use statistical software to estimate the relationships among variables as specified in your model. The analysis provides estimates for direct paths (direct effects) and indirect paths (mediated effects) between variables. In this study Path analysis to model and assess the relationships and effects between different influencing factors. Data Collection: Surveys and interviews with fuel-powered bike owners and e-bike users. The study are primary in nature, Data collection was done through the structural questionnaire. The size of the sample is limited to 100 users based on convenient sampling. Analysis:



Structural equation

V1 to V2 = r1*(P_{21})
V1 to V3 = r2*(P_{31})
V4 = $P_{41}+P_{42}+P_{43}+R_u$
V5 = $P_{52}+P_{54}+R_u$
V6 = $P_{63}+P_{64}+P_{65}+R_u$

Correlation matrix

	V1	V2	V3	V4	V5	V6
V1	1	0.437**	-0.004	0.394**	0.008	0.049
V2	0.437**	1	0.2	0.481**	0.218	0.069
V3	-0.004**	0.2	1	0.184	0.199	0.397**
V4	0.394**	0.481**	0.184	1	0.133	-0.114
V5	0.008	0.218	0.199	0.133	1	0.107
V6	0.049	0.069	0.397**	-0.114	0.107	1

Structural equation

V1 ⟶ V2 = 0.437**
V1 ⟶ V3 = -0.004

V4(More Trendy) = $P_{41}+P_{42}+P_{43}+R_u$

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.259[a]	.067	.038	.7556

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	
		B	Std. Error	Beta	t	Sig.
1	(Constant)	3.667	.378		9.710	.000
	EV Comfort ability	-.116	.096	-.150	-1.209	.230
	EV Refilling	.006	.094	.007	.065	.948
	EV Eco Friendly	.225	.086	.298	2.621	.010

V4 (More Trendy) = P_{41} (Refilling) + P_{42} (Comfort) + P_{43} (Eco-Friendly) +R_u
= -0.150(Ref) + 0.007 (Com) + 0.298 (Eco) + R_u
$R_u = \sqrt{1- R^2}$
$= \sqrt{1-(0.67)^2}$
= 0.9976

V5(Affordability) = $P_{52}+P_{54}+R_u$

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.482[a]	.232	.216	.8704

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.642	.357		4.597	.000
	EV Comfortability	.479	.127	.487	3.772	.000
	EV MoreTrendy	-.007	.137	-.007	-.051	.960

V5 (Affordable Price) = P_{52} (com) + P_{54} (Trendy) +R_u
= 0.487 (Com) + 0.007 (Com) + R_u
= 0.487 (Com) + 0.007 (Com) + 0.9727
$R_u = \sqrt{1-R^2} = \sqrt{1-(0.232)^2}$
=0.9727

V6 (E-Bike Satisfaction level) = $P_{63}+P_{64}+P_{65}+R_u$

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.466[a]	.217	.166	.37166

V6 (E-Bike Satisfaction Level) = P_{63} (Eco) + P_{64} (Trend) + P_{65} (Aff) +R_u
= 0.442 (Eco) + 0.218 (Trendy) + 0.156 (Aff) +R_u
= 0.442 (Eco) + 0.218 (Trendy) + 0.156 (Aff) +0.9762

$R_u = \sqrt{1-R^2}$
$= \sqrt{1-(0.217)^2}$
= 0.9762

Identification of the direct effect of the variables

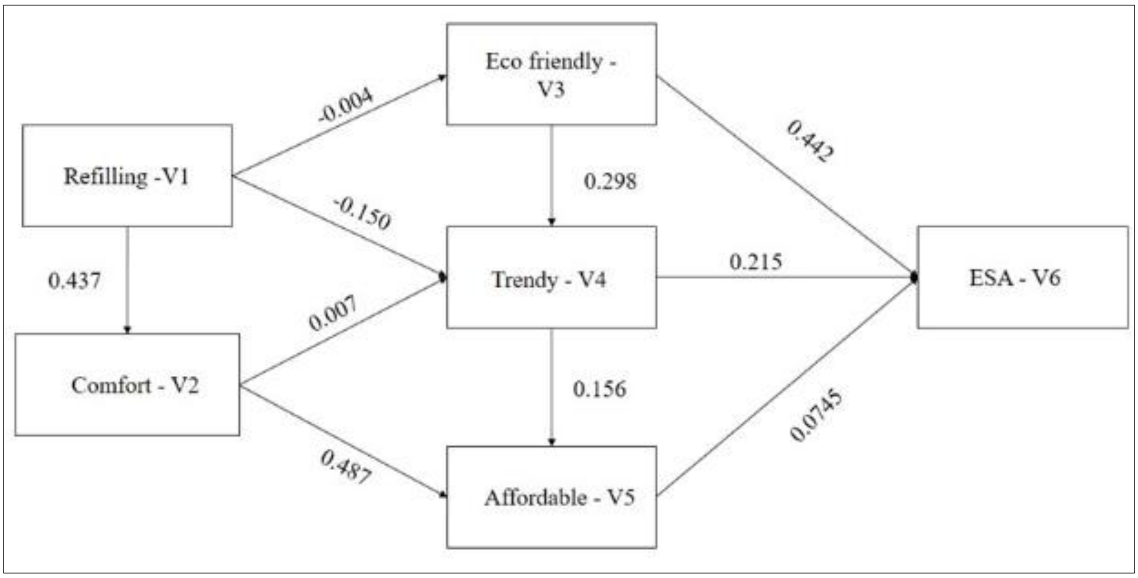
Direct effect	Path Co-efficient	Value
V1 → V2	P_{21}	0.437
V1 → V3	P_{31}	-0.004
V1 → V4	P_{41}	-0.150
V2 → V4	P_{42}	0.007
V2 → V5	P_{52}	0.487
V3 → V4	P_{43}	0.298
V3 → V6	P_{63}	0.442
V4 → V5	P_{54}	-0.007
V4 → V6	P_{64}	-0.218
V5 → V6	P_{65}	0.156

Identification of Indirect Effect of the variables

V1 → V2 → V4 = P_{21} * P_{42} = (0.437 * 0.007) = 0.0031
V1 → V2 → V5 = P_{21} * P_{25} = (0.437 * 0.487) = 0.2128
V1 → V3 → V6 = P_{31} * P_{63} = (-0.004 * 0.442) = 0.0018
V1 → V4 → V6 = P_{41} * P_{64} = (-0.150 * -0.218) = 0.0329
V2 → V4 → V6 = P_{42} * P_{64} = (0.007 * -0.2180 = -0.0015
V2 → V5 → V6 = P_{52} * P_{65} = (0.487 * 0.156) = 0.076
V3 → V4 → V6 = P_{43} * P_{64} = (0.298 * -0.218) = -0.065
V4 → V5 → V6 = P_{54} * P_{65} = (-0.007 * 0.156) = 0.0007
V1 → V2 → V4 → V6 = P_{21} * P_{42} * P_{64} = (0.437 * 0.007 * -0.218) = -0.0006
V1 → V2 → V5 → V6 = P_{21} * P_{52} * P_{65} = (0.437 * 0.487 * 0.156) = 0.0331
V1 → V3 → V4 → V6 = P_{31} * P_{43} * P_{64} = (-0.004 * 0.298 * -0.218) = 0.2598
V1 → V4 → V5 → V6 = P_{41} * P_{54} * P_{65} = (-0.150 * -0.007 * 0.156) = 0.0001

Direct & Indirect Effects

Endogenous Variable	Exogenous Variable	Direct Effect	Indirect Effect	Total Effect	Total Association	Non-Casual
V4	V1	-0.150	0.0031	-0.1469	0.394	0.5409
	V2	0.007	-	0.007	0.481	0.474
	V3	0.298	-	0.298	0.184	-0.114
V5	V1	-	0.2128	0.2128	0.008	-0.2048
	V2	0.487	-	0.487	0.218	-0.269
	V3	-	-	-	0.199	0.199
	V4	-0.007	-	-0.007	0.133	0.14
V6	V1	-	0.0389	0.0389	0.049	0.0101
	V2	-	0.0745	0.0745	0.069	0.0055
	V3	0.442	-0.065	0.377	0.397	0.02
	V4	-0.218	-0.011	-0.229	0.114	-0.343
	V5	0.156	-	0.156	0.107	-0.049



Discussion and Conclusion

From the above table the results revealed that the direct path between V3 (Eco-Friendly) & V6 (Electric bike satisfaction) is found to be the highest (0.442). Hence people prefer electric bikes because of the eco-friendly nature of the vehicle the indirect path V1 & V5 shows 0.2128 as highest effect. Among the indirect paths to V6, V2-V5-V6 is considered to be the highest (0.0745). Hence the variables comfort ability and affordable price shows a high indirect effect towards the satisfaction level Population Current owners of fuel-powered bikes who are potential or existing e-bike users. Factors to Explore Cost of e-bikes, fuel cost savings, environmental impact, technological adoption, and consumer attitudes.

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