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Research Article

Unleashing the Factors Inducing the Adoption of Electric Vehicles (EVs) in Bangladesh: A PLS-SEM Approach

S.M. Masudur Rahman[1,2], Sadman Kabir[3], Md. Johir Rayhan[4], Abu Naser Mohammad Saif[5,6,7,*], Nayan Miah[8], Abdullah Al Mamun[9]

[1]Department of Business Administration, Northern University Bangladesh, Dhaka, BANGLADESH.
[2]School of Business, Faculty of Business, Design and Arts, Swinburne University of Technology, Sarawak, MALAYSIA.
[3]Department of Business Administration-General, Faculty of Business Studies, Bangladesh University of Professionals (BUP), Mirpur Cantonment, Dhaka, BANGLADESH.
[4]Department of Banking and Insurance, Faculty of Business Studies, University of Dhaka, Dhaka, BANGLADESH.
[5]School of Business and Economics, Universiti Putra Malaysia, Serdang, Selangor, MALAYSIA.
[6]Department of Management Information Systems, Faculty of Business Studies, University of Dhaka, BANGLADESH.
[7]Research Fellow and Adjunct Faculty, Department of Business Studies, State University of Bangladesh, Dhaka, BANGLADESH.
[8]Department of Finance, Faculty of Business Studies, University of Rajshahi, Rajshahi, BANGLADESH.
[9]Department of Marketing, Jashore University of Science and Technology, Jashore, BANGLADESH.

ABSTRACT

Global Electric Vehicle (EV) market growth has garnered attention as an avenue to curb the discharge of greenhouse gases and confront the effects of climate change. Policymakers, industry stakeholders and researchers must comprehend the factors influencing EV adoption. This study investigates the components affecting the introduction of electric vehicles in Bangladesh due to its prominence. The study examines how affordability, insufficient infrastructure and after-sales service affect electric vehicle initiation in Bangladesh through a comprehensive survey of a diverse group. These factors significantly influence EV adoption trends in Bangladesh and the study employs descriptive and inferential statistics to assess their impact. Valid data were analyzed using SmartPLS 4. The study reveals that affordability and infrastructure act as impediments to Bangladesh's adoption of electric vehicles, underscoring the pivotal role of cost in consumer decision-making. To boost EV adoption in the country, there's a need for financial incentives and reduced upfront costs for EVs. Conversely, the study indicates that after-sales service does not significantly affect electric vehicle adoption in Bangladesh. Given these results, policymakers and industry stakeholders should prioritize affordability to accelerate EV adoption and enhance infrastructure and after-sales services to improve the EV ownership experience. These insights can aid policymakers and stakeholders in promoting sustainable transportation and EV adoption in Bangladesh, ultimately contributing to climate change mitigation and global air quality improvement. Additionally, the conclusions derived can serve as a foundation for further investigation, exploring socio-economic, political and macroeconomic variables in greater depth.

Keywords: Electric Vehicle Adoption (EVA), Affordability, Insufficient infrastructure, Service after-sales, PLS-SEM, SmartPLS.

Correspondence:
Abu Naser Mohammad Saif
School of Business and Economics, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, MALAYSIA.
Department of Management Information Systems, Faculty of Business Studies, University of Dhaka, BANGLADESH.
Email: saif@du.ac.bd; saif.mohammad911@gmail.com
ORCID: 0000-0001-7078-6780

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INTRODUCTION

There exists a growing recognition that Electric Vehicles (EVs) are an effective means to help alleviate the consequences of climate change and cut carbon emissions. The integration of Electric Vehicles (EVs) has the capacity to substantially mitigate the discharge of greenhouse gas, enhance air quality and reinforce energy independence. However, despite the benefits of EVs, their adoption remains slow in various regions of the globe, including Bangladesh. In Bangladesh, the infrastructure and market structure needed for Zero-Emission Cars (ZEVs) are still in their infancy. ZEVs are still a relatively new technology. Due to the high price of batteries, EVs have a substantially higher purchase price than similar Conventional Vehicles (CVs). Norway, as the leading global market for electric vehicles, has achieved significant market saturation of EVs through expansive incentive schemes such as complimentary parking, exemption from road taxes and reduced-price differentials between Conventional Vehicles (CVs) and EVs.[1] This phenomenon stems from the principle that consumers will only embrace new technologies if they perceive them to outperform conventional vehicles.

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The World Health Organization (WHO) reports that contamination of the air is a significant global problem that affects 9 out of 10 people worldwide and is thought to be the cause of seven million deaths annually.[2] The primary contributor to this pollution is vehicle emissions, as reported by the WHO in 2019. It is especially concerning that 9 of the 10 cities with the highest pollution worldwide are located in India.[2] Conventional vehicles are partially to blame for this since they discharge poisonous fumes into the open air and don't adhere to Indian emission regulations.[3] It is widely accepted that replacing fossil fuel-powered conventional vehicles with Electric Vehicles (EVs) is a necessary step toward reducing environmental damage, conserving energy and minimizing noise pollution. The Bangladeshi government has taken many steps to reduce environmental damage, save energy and minimize noise pollution. From those actions, the electric vehicle is one of them. They want to cut the use of fuel for vehicles.

The Bangladeshi government has initiated several measures to foster the use of EVs, including tax incentives, import duty waivers and the installation of facilities for charging vehicles. Although the government has made efforts to capitalize on the various beneficial features of EVs, there is still resistance to their adoption. Various stakeholders have cited multiple reasons for this resistance. Automakers, for example, are hesitant to switch to manufacturing EVs due to high infrastructure costs, affordability and after-sale service concerns. Prospective customers may also have reservations about adopting EVs due to range anxiety, high prices and concerns about resale value.[4] Several factors influence the adoption of EVs, including cost, range, charging infrastructure and public awareness. A study found that cost is the primary barrier to EV adoption globally.[5] Similarly, researchers showed that high initial costs or affordability, after-sales service and limited charging infrastructure are significant factors inhibiting EV adoption in Bangladesh.[6]

Additionally, a study found that a lack of public awareness and perception of EVs as inferior to traditional gasoline vehicles are significant barriers to adoption in Bangladesh.[7] Additionally, suppliers have expressed resistance due to their dependence on imported raw materials, particularly nickel and lithium, which can result in longer delivery times in the distribution system. However, the adoption rate of EVs in Bangladesh remains low, though it is imperative to comprehend these impacting elements and address them to increase the adoption of EV.

Therefore, this paper investigates the drivers that influence the proliferation of Electric Vehicles (EVs) in Bangladesh with the aim of effectively navigating this gap and proposing suggestions to policymakers, industry stakeholders and consumers to foster the adoption of EVs.

Consequently, the inquiry employs a mixed-methods approach to identify the determinants affecting the introduction of EVs in Bangladesh. By conducting a thorough analysis of the literature and collecting data through a survey with self-administrative questionnaires, this study will provide significant insights regarding the attitudes and perceptions towards embrace of EVs in Bangladesh. The outcomes of this research will be valuable to the expanding field of literature on sustainable transportation and will provide valuable information for stakeholders interested in promoting EV adoption in Bangladesh.

Hence, given this background, the objectives of the research in addressing the underlying problem(s) are as follows:

To ascertain the determinants that influence EV adoption in Bangladesh.

To investigate the relationship between the identified factors and EV adoption in Bangladesh.

Theoretical Background and Hypotheses Development

In this study, a few theories are applicable, like the Technology Acceptance Model (TAM), Innovation Diffusion Theory (IDT), Social Network Theory (SNT) and Theory of Planned Behavior (TPB). Among those theories, we consider the TPB theory because TAM, IDT and SNT are not appropriate, as they mainly focus on technological innovation.[8] TAM primarily focuses on internal factors, such as the perception of usefulness as well as perceived user convenience in determining technology adoption.[9] However, in the case of EV adoption in Bangladesh, several external factors play a significant role, such as infrastructure availability, government policies, charging network accessibility and cultural factors. TAM's narrow focus on internal factors may not adequately capture the complexity of the external environment affecting EV adoption.[10] IDT primarily focuses on the diffusion process at a macro level, considering the aggregate adoption patterns in a population.[11] It does not extensively address individual-level components that affect decisions about adoption. In the case of EV adoption in Bangladesh, individual-level factors such as attitudes, beliefs, perceived benefits and perceived risks play a crucial role. IDT may not adequately capture these individual-level factors and their influence on EV adoption.[12] And, SNT tends to focus more on the micro-level analysis of social relationships and may not extensively address the broader contextual factors influencing behavior.[13] In the case of EV adoption, contextual factors such as infrastructure availability, government policies, charging network accessibility and cultural norms can significantly influence adoption decisions. SNT's limited consideration of these contextual factors may limit its explanatory power in understanding EV adoption in Bangladesh.[14]

However, while TPB offers a comprehensive framework that integrates individual-level certain aspects including viewpoints, subjective standards and perceived control over behavior, as well

as contextual factors,[15] the Technology Acceptance Model (TAM) primarily emphasizes on internal determinants like perception of usefulness and user convenience. TPB's inclusion of subjective norms, which reflect social factors' effect on behavior, provides a distinct advantage over TAM, which lacks explicit consideration of social influence. In this regard, TPB facilitates a deeper analytical exploration of individuals' viewpoints, subjective standards and perceived control over behavior concerning the adoption of electric vehicles, particularly regarding factors such as inadequate infrastructure, after-sale support and cost.[16] By encompassing both internal and external determinants, TPB offers a more thorough comprehension of the complexities affecting EV adoption, thus providing valuable insights for researchers and policymakers alike.

Hypothesis Development

Insufficient Infrastructure and Electric Vehicle (EV) Adoption

In many countries, including Bangladesh, the availability and accessibility of charging infrastructure significantly influence consumers' propensity to purchase EVs.[17] Without a reliable and sufficient charging infrastructure, consumers may experience range anxiety, increased charging times and reduced convenience, which can discourage them from adopting EVs.[18] This can, in turn, limit the market demand for EVs and slow down the transition to sustainable transportation.

In Bangladesh, the availability of charging infrastructure for EVs is still limited despite the government's initiatives to establish charging stations. This lack of infrastructure can be a significant challenge to the acceptance and use of EVs in the country,[19] where consumers heavily rely on public charging infrastructure to recharge their vehicles.

Therefore, developing a hypothesis on "Insufficient Infrastructure and Electric Vehicle (EV) Adoption" is as follows:

H1: Inadequate infrastructure is significantly related to the adoption of EVs in Bangladesh.

This will investigate the association between infrastructure and the adoption of EVs in Bangladesh. This hypothesis can guide the study in analyzing the present conditions of infrastructure for charging and identifying the difficulties consumers face in accessing and using charging facilities. Ultimately, the analysis can provide insights into how policymakers and stakeholders in the industry can form strategies to improve charging infrastructure and promote the acceptance and use of EVs in Bangladesh.

Affordability and Electric Vehicles Adoption

Affordability and EV adoption are already discussed in existing literature, which suggests that the cost of EVs is a fundamental variable influencing consumers' willingness to buy them.[20]

Studies have shown that the high cost of EVs at the initial stage is a single among the main hurdles to their extensive adoption, particularly in low- and middle-income countries like Bangladesh.[7] EVs are generally costlier than traditional vehicles because their batteries and other components require more costs than their counterparts.[21] This can make them unaffordable for many consumers, particularly those with limited income.

In Bangladesh, where most of the population belongs to the lower-middle-income group, the higher cost of EVs can considerably challenge their adoption.[22] This can limit the market demand for EVs and slow down the transition to sustainable transportation.

Therefore, developing a hypothesis on "Affordability and EV Adoption" as the following:

H2: Affordability significantly influences the adoption of EVs.

This study will look into the association between the cost of EVs and their adoption rate in Bangladesh. The hypothesis suggests a strong correlation exists between EVs' affordability and adoption rate. This hypothesis can guide the study in analyzing the current pricing and financing models of EVs in Bangladesh, identifying the components that influence the cost of EVs and exploring the strategies that can be used to make EVs more affordable for consumers. Ultimately, the study can provide insights into how policymakers and industry stakeholders can develop policies and campaigns to encourage the use of electric vehicles in Bangladesh by addressing affordability.

Service after Sales and Electric Vehicles Adoption

The hypothesis on "Service after Sales and Electric Vehicles Adoption" suggests that the availability and quality of after-sales service is an essential element in the adoption of EVs.[23]

In Bangladesh, the lack of adequate after-sales service is a significant challenge to the introduction of EVs.[24] The technology used in EVs is relatively new and most mechanics are not trained to repair or maintain EVs. This lack of knowledge and expertise can result in extended downtime for the vehicle and increase the cost of ownership for the customer. Moreover, the availability of spare parts for EVs is also limited in the country, making it challenging to repair the vehicle.

Therefore, developing a hypothesis on "Service after sales and EV adoption" as follows:

H3: Service after sales is an influential factor for electric vehicle adoption.

According to the hypothesis, there might be a strong relationship between the rate of EVs adoption and the type and availability of after-sales support. This hypothesis can guide the study in analyzing the current state of after-sales service for EVs in Bangladesh and identifying the challenges consumers face in maintaining and repairing their vehicles.

METHODOLOGY

This quantitative study examines the variables influencing the uptake of EVs. The dependent variable is the EVs adoption, with insufficient infrastructure, affordability and service after sales as the independent variables.

Data Collection and Sampling

With various questions on influencing variables, the researcher will survey the owners to learn about their use of Electric Vehicles (EVs) and their reasons for not utilizing them. Additionally, the authors compile data on the effects of EVs from reliable sources like the Scopus database and other journals. The tool adopted in this research to collect data is a self-administered questionnaire. There are two sections of this questionnaire, section A and section B. Section B contains items for variables, whereas Section A contains demographic variables. Items in Section B are constructed based on the three independent variables and one dependent variable. The Likert scale is adopted to analyze all observed variables. The options will be a 5-point Likert scale where 1 implies strongly disagree, 2 implies disagree, 3 implies neutral, 4 implies agree and 5 implies strongly agree.

The sample for this study will be selected randomly to avoid biases. The sample size will be enough to represent the whole population. In this study, authors consider 384 samples as a sample size of at least 384 is required for an area with a population of 100,000 or more to reflect the respondents in the selected population accurately;[25] and it is still possible to conduct a meaningful survey study with careful planning and consideration of the research objectives and limitations.[26] The data collection process will be carried out through a structured questionnaire. The questionnaire will be developed based on the variables that are believed to affect the adoption of EVs in Bangladesh. The questionnaire will be pretested before the actual data-gathering process to ensure the clarity and appropriateness of the questions.

Regression Model

Multiple regression models for this study are given below.

$$EVAs=\beta0+\beta1A+\beta2II+\beta3\ SAS+\mu i$$

Here,

EVAs=Electric vehicle adoption (Dependent variable)

β0=Constant

β1=Coefficient of Affordability

A=Affordability (independent variable)

β2=Coefficient of Insufficient Infrastructure

II=Insufficient Infrastructure

β3=Coefficient of Service after Sales

SAS=Service after Sales

Data Analysis

SmartPLS and Bootstrapping

Researchers utilize SmartPLS 4 to perform calculations and construct and validate models. SmartPLS represents a second-generation Structural Equation Modeling (SEM) technique.[27] The path model within SmartPLS facilitates the depiction of relationships between variables and indicators through a clear diagram, aiding researchers in presenting their findings.[28] Unlike other SEM methods, SmartPLS does not necessitate distributional assumptions,[29] allowing for greater flexibility in data collection. Additionally, SmartPLS enables the testing of both reflective and formative scales. Also, SmartPLS does not limit the use of formative and reflective models within a single construct.[28] Therefore, in this study, SmartPLS is employed for data processing, as it is a reliable tool for testing complex models and structures.

Non-parametric bootstrapping tests the significance of different results in Partial Least Squares Structural Equation Modeling (PLS-SEM), including HTMT, path coefficients, R^2 values and Cronbach's alpha.[30] Unlike conventional methods, PLS-SEM does not presume a normal distribution of data, making it inappropriate to employ parametric significance tests to catch up on the importance of path coefficients, outer loadings and outer weights. Consequently, bootstrapping is employed to validate the effectiveness of predicted path coefficients in PLS-SEM.[31,32]

Ethical issues

For this study, consent from the participants was verified. The design and execution of studies, concern for society and other people, the use of resources and study results, scientific fraud and the regulation of research are essential ethical standards to which we adhere in our research operations. The topic of the current investigation is free from any form of organizational pressure. Each participant had enough time throughout data collection to answer questions openly and honestly. Personal gateways for data collecting did not exist. The researchers carefully stored every questionnaire they collected and forbade anybody else from using them. In this study, the data were simply used for analysis. After ensuring integrity, the authors used the data for analysis and reporting. Instead of reporting personal information by name, all facts were presented imperiously and objectively.

Data Analysis and Findings

Respondent Demographic Profile

The survey evaluates the respondents' demographic profile on several factors, including age group, marriage status, employment status, monthly personal income, educational attainment, marital status, place of residence and vehicle ownership status,

consideration of purchasing an electric vehicle, aware of any government incentives and so on.

Table 1 shows that male participants comprised 82.61% of the participants, whereas female participants comprised 17.39% of the participants in this study on electric vehicle adoption. The respondents within age group of 18-25 and 25-35 is higher, indicating that young people are more interested in electric vehicle adoption. The marital status shows that the percentage of single persons is 52.95 and of married persons is 42.65, indicating that single persons are more interested. 77.14% of people own any vehicle, implying they are also interested in electric vehicles. 85.29% of the respondents are under the consideration of purchasing an electric vehicle.

Measurement Model Assessment

Internal Consistency Reliability and Convergent Validity

SmartPLS does not offer goodness-of-fit statistics commonly used in covariance-based structural models. Instead, reliability measures are used to assess the level of fitness. Three reliability metrics, namely composite, convergent and discriminant, are employed to evaluate the internal consistency and dependability of the model.

Composite reliability is a method that assesses measurement reliability by considering the inter-correlations among the observed indicator variables.[33] A composite reliability score should be at least 0.60 to be deemed satisfactory. Considering the results shown in Table 2, the three independent variables, namely insufficient infrastructure (0.956), affordability (0.942), service after sales (0.942) and the dependent variable, electric vehicle adoption (0.974), exhibit a high level of internal consistency. These results indicate strong composite reliability for the constructs, with scores ranging between 0.90 and 1.00.

Cronbach's alpha is a measure used to gauge the internal uniformity of a test by examining the degree to which the items are closely allied to one another.[34,35] Acceptable alpha values range from 0.50 to 1.00 .In the present study, the alpha values for insufficient infrastructure (.944), affordability (.926), service after sales (.935) and electric vehicle adoption (.969) as the dependent variable indicate sufficient levels of internal consistency. This suggests that the items within each reflective construct are highly interrelated, with reliabilities exceeding 0.90.

The Average Variance Extracted (AVE) metric is used to evaluate the convergent validity of the indicator variables.[36] An AVE value of 0.50 is considered satisfactory, while 0.70 or higher indicates excellent validity, as it demonstrates that over half of the variables are accounted for.[37] Examining Table 3, the AVE results reveal that the Insufficient Infrastructure (II), Affordability (A) and Service After Sales (SAS) independent variables have AVE values of 0.782, 0.767 and 0.764, respectively. The dependent variable, Electric Vehicle Adoption (EVA), has an AVE of 0.822.

Reflective models place greater emphasis on outer loadings, which capture the relationship between a latent construct and its indicator variables.[38] Outer loadings represent the degree to which the indicator variables adequately represent the construct that underlies them. Each indicator variable's regression on its respective construct estimates the outer loading, reflecting how much each indicator contributes to explaining the latent variable. Standardized outer loadings of indicators on a construct should exceed 0.70.[39,40] Upon examination, it is evident that all indicator values for each construct surpass the threshold of 0.70.

Discriminant Validity Using Fornell-Larcker Criterion

Fornell-Lacker's method entails evaluating the correlation between latent constructs and the square root of the AVE. It underscores that the variance of indicators associated with a construct offers a more refined delineation than the variance of other latent constructs. This is established by squaring the AVE for each construct, with the resultant value anticipated to surpass correlations with other latent constructs.[37]

In light of the results shown in Table 3, the values for the independent variables, namely Insufficient Infrastructure (II), Affordability (A) and Service After Sales (SAS), are 0.885, 0.876 and 0.874, respectively. The dependent variable, Electric Vehicle Adoption (EVA), has a value of 0.907. These values demonstrate that results are acceptable. Moreover, the diagonal values (within the same construct) are higher than the off-diagonal inter-construct correlations. This suggests that none of the associations between pairs of latent variables are more extensive than, or even close to, the square roots of the AVE values for the variables. Consequently, the results indicate no significant issues with discriminant validity, demonstrating that each latent variable is distinct from the others.

Discriminant Validity Using Heterotrait-Monotrait Ratio (HTMT)

A simulation approach has demonstrated that cross-loading and the Fornell and Larcker Test may not consistently detect the absence of discriminant validity in typical research contexts. Recognizing this limitation in the existing model of discriminant validity, an alternative and superior method called HTMT is proposed to analyze the distinct nature of constructs.[41] This relatively new technique, applied in Structural Equation Modeling (SEM), provides consistent and robust results. In order to establish discriminant validity, all HTMT values for conceptually distinct constructs should be below 0.85.[42]

Based on the findings presented in Table 4, all HTMT values are found to be less than 0.85. Therefore, the outcomes from Table 4 show that discriminant validity is observed among all the other constructs.

Table 1: Demographic Profile.

Demographic Characteristics		Number	Percentage
Gender	Male	317	82.61%
	Women	67	17.39%
Age Group	18-25	147	38.24%
	25-35	187	48.53%
	36-45	28	7.35%
	46-55	17	4.41%
	65 above	6	1.47%
Marital status	Married	164	42.65%
	Single	203	52.94%
	Divorced	11	2.94%
	Widowed	6	1.47%
Employment Status	Employed (Full Time)	203	52.94%
	Employed (Part-Time)	40	10.29%
	Self Employed	23	5.88%
	Student	118	30.88%
Personal monthly income	20,000 bdt. to less than 30,000 bdt.	152	39.71%
	30,000 bdt. to less than 40,000 bdt.	84	22.06%
	40,000 bdt. to less than 50,000 bdt.	84	22.06%
	50,000 bdt. to less than 60,000 bdt.	34	8.82%
	60000 bdt. or more	28	7.35%
Educational level	Primary School	11	2.94%
	Certificate/Foundation/Diploma	28	7.35%
	secondary level	6	1.47%
	Bachelor Degree	248	64.71%
	Master Degree	68	17.65%
	Doctoral Degree	23	5.88%
Place	Dhaka	124	32.35%
	Khulna	85	22.06%
	Rajshahi	90	23.53%
	Barishal	40	10.29%
	Chattogram	45	11.76%
Ownership of vehicle status	Yes	326	84.94%
	No	58	15.06%
Consideration of purchasing an electric vehicle	Yes	327	85.29%
	No	57	14.71%

Structural Model and Hypothesis Testing

Model Fit Tests

The Standardized Root Mean Square Residual (SRMR) differs from the Root Mean Square Residual (RMSR) as it involves converting both the sample covariance matrix and the projected covariance matrix into correlation matrices. The SRMR evaluates the difference between the actual correlation matrix and the correlation matrix reflected by the model. By examining the average differences between observed and expected correlations, it provides a measure for evaluating how well the model works. A threshold value of 0.08, or alternatively less than 0.10 for a more conservative approach,[43] is commonly considered indicative of a satisfactory fit. It is recommend using the Standardized Root Mean Square Residual (SRMR) as a metric for assessing goodness-of-fit in PLS-SEM to reduce the risk of misrepresenting the model.[44]

Table 2: Construct Reliability and Validity.

	Cronbach's Alpha	Composite Reliability (rho_a)	Composite Reliability (mo_c)	AVE
A	0.926	1,100	0.942	0.767
EVA	0.969	0.976	0.974	0.822
II	0.944	0.951	0.956	0.782
SAS	0.935	1.205	0.942	0.764

Table 3: Discriminant Validity (Fornell-Larcker criterion).

	A	EVA	II	SAS
A	0.876			
EVA	-0.214	0.907		
II	0.0128	0.639	0.885	
SAS	0.634	0.199	0.006	0.874

Table 4: Discriminant Validity (HTMT).

	A	EVA	II	SAS
A				
EVA	0.192			
II	0.209	0.654		
SA S	0.763	0.142	0.160	

Table 5: Model Fit.

	Saturated Model	Estimated Model
SRMR	0.093	0.093
d_ULS	2.616	2.616
d_G	2.753	2.753
Chi-square	751.174	751.174
NFI	0.683	0.683

According to the values presented in Table 5, the SRMR value is calculated as 0.090, which falls within an acceptable range of less than 0.10.

Researchers outline two different approaches to compute the discrepancy: d ULS, which refers to the squared Euclidean distance and d G, which represents the geodesic distance.[45,46] In the present study, the values for d ULS and d G are determined to be 2.616 and 2.737, respectively.

The Normed Fit Index (NFI) is one of the initial fit metrics in the field of Structural Equation Modeling (SEM).[47] The NFI is computed by subtracting the Chi^2 value of the suggested model from the Chi^2 value of the null model and then dividing it by the Chi^2 value of the null model. The resulting NFI values range between 0 and 1, with higher values indicating a better fit.[48] However, these explanations can be challenging for practitioners to comprehend. In the present study, the NFI value, as shown in Table 5, is calculated as 0.683, which is equivalent to 60% of the maximum value. This suggests a reasonably good fit. It is worth noting that the Chi-Square score in this study is 751.174.

Path Relationship Evaluations

Path coefficient analysis is employed to examine the direct association between the independent variables and Electric Vehicle Adoption in Bangladesh (EVA). For this analysis, a significance level of α=0.05 is set and the examination will be conducted according to the results demonstrated in Table 6 and Figure 1.

Initially, the findings indicate that the affordability factor (C=-0.295, P=0.164) is not statistically significant due to its p-value exceeding 0.05. This suggests that the coefficient of the affordability factor is 0.164, which does not significantly impact the dependent variable, EVAs. Consequently, H1 is not supported. Secondly, the p-value for the insufficient infrastructure factor is lower than 0.05 and the t-value is greater than 2.00, suggesting a significant positive direct effect of the insufficient infrastructure factor on electric vehicle adoption in Bangladesh (EVA). Thus, H2 is supported. However, the final independent factor, service after sales, does not exhibit a significant influence on Electric Vehicle Adoption in Bangladesh (EVA), with a p-value of 0.910 (higher than 0.05) and a t-value of 0.113 (less than 2). So, we can conclude that the result table can illustrate that from three independent variables, Insufficient Infrastructure (II), Affordability (A) and Service After Sales (SAS), one independent variable is found to be significantly positive to the dependent variable, Electric Vehicle Adoption (EVA) and other two variables are not significant.

Table 6: Path Coefficient-Mean, T values, *P* values.

	Coefficient	T statistics	*p* values	Hypothesis
A-> EVA	-0.285	1.393	0.024**	H1 is Supported**
II -> EVA	0.676	6.095	0.000**	H2 is Supported**
SAS -> EVA	-0.024	0.113	0.91	H3 is not Supported

p<0.05 is Significant**T<2 is Insignificant Note: Electric vehicle adoption in Bangladesh (EVA) as the dependent variable.

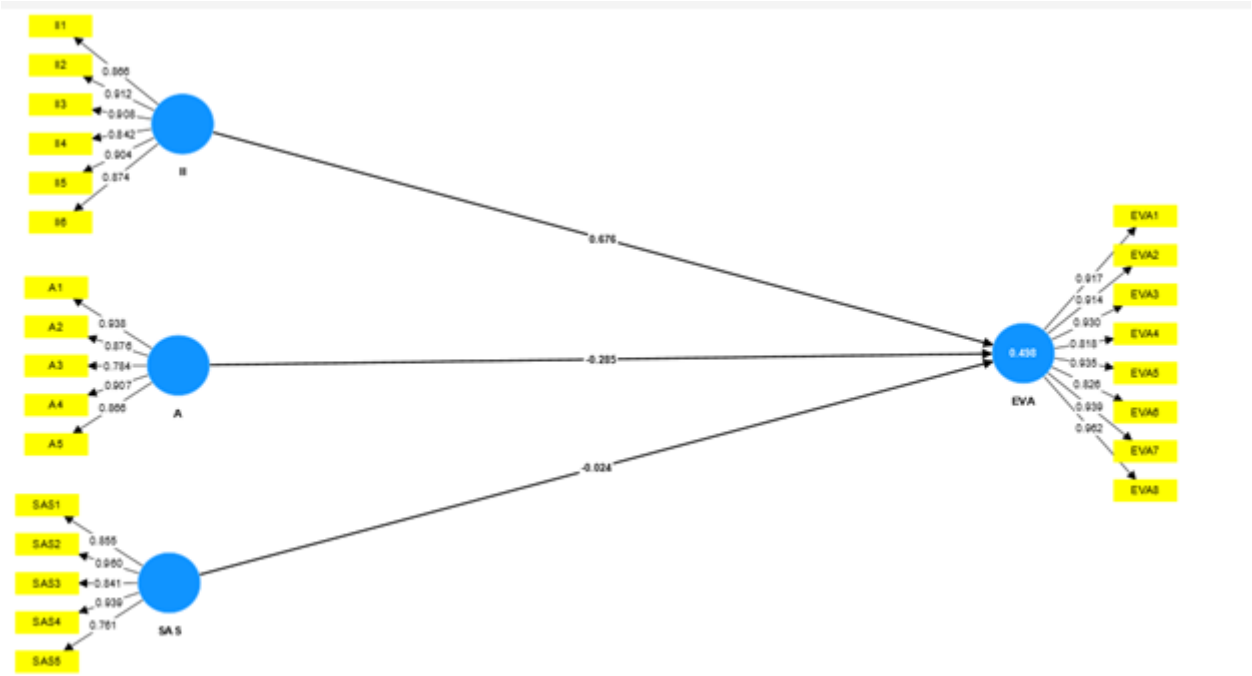

Figure 1: Structural Model for Electric Vehicle Adoption.

DISCUSSION

Affordability factors significantly influence Electric Vehicle Adoption (EVA) in Bangladesh, as ascertained by the t-test, where the t-value is larger than two and the *p*-value is less than 5% (t-value 1.393 and *p*-value .164). In the same way, insufficient infrastructure factors have a significant effect on Electric Vehicle Adoption (EVA) in Bangladesh, as determined by the t-test, where the t-value is higher than 2 and the p-value is less than 5% (t-value 6.095 and the *p*-value .000). Thus, H1 and H2 are supported. Conversely, service after-sales factors have an insignificant effect on Electric Vehicle Adoption (EVA) in Bangladesh, as determined by the t-test, where the t-value is less than 2 and the p-value is higher than 5% (t-value .113 and *p*-value .913). Hence, H3 is not supported.

Researchers also have the same line of outcomes, which is consistent with the fact that affordability factors have a significant effect on Electric Vehicle Adoption (EVA).[49,50,51] Some researchers also revealed the same line of findings, which means insufficient infrastructure have a significant effect on electric vehicle adoption (EVA).[52,53,54] Affordability and insufficient infrastructure factors can indeed play an important role in Electric Vehicle Adoption (EVA) in any country, including Bangladesh.

For several reasons, affordability factors also affect Electric Vehicle Adoption (EVA) in Bangladesh. The upfront expense of Electric Vehicles (EVs) is generally higher than that of traditional Internal Combustion Engine Vehicles (ICEVs). This cost difference makes EVs less affordable for many potential buyers in Bangladesh, where the average income levels are relatively low. Higher purchase costs can act as a barrier, preventing individuals from considering EVs as a viable option. The affordability of EVs is closely linked to the proximity and accessibility of charging facilities.[55] In Bangladesh, the charging infrastructure for EVs is still in its inception of development.[56] Limited charging stations and a lack of widespread coverage can make it inconvenient for EV users to recharge their vehicles, especially in areas with inadequate infrastructure. This lack of accessibility further hampers the adoption of EVs, as it may require additional investments in personal charging infrastructure, which can be costly. Affordability factors are closely tied to government policies and financial incentives. In Bangladesh, the government has taken initiatives to foster EV adoption by providing tax benefits, import duty exemptions and subsidies for EVs. However, the impact of

these incentives on affordability depends on their effectiveness and reach. If these policies are not effectively implemented or widely communicated, potential EV buyers may not perceive EVs as financially viable options.

Insufficient infrastructure significantly impacts Electric Vehicle Adoption (EVA) in Bangladesh for several reasons. A robust and widely available charging infrastructure across the country is essential for the initiation of electric vehicles. However, in Bangladesh, the charging infrastructure has yet to see the light of development. The scarcity of charging stations and their uneven distribution across the country make it inconvenient for potential electric vehicle owners to charge their vehicles.[56] The lack of a well-developed charging network leads to range anxiety, as consumers may worry that they might run out of battery life before they arrive at a charging station. This uncertainty hampers the embrace of electric vehicles. Research by the International Energy Agency in 2017 found that there is limited presence of charging infrastructure in Bangladesh. The study found that there are only around a hundred charging stations in Bangladesh, which is far from the number of charging stations needed to support many electric vehicles. Another reason is that public charging stations are mandatory to provide accessibility and convenience for electric vehicle owners, particularly for those who do not have access to private charging facilities. In Bangladesh, public charging stations are very scarce, which poses a significant challenge for electric vehicle owners. Without adequate charging points in public spots like parking spaces, shopping malls and residential areas, potential buyers may be deterred from considering electric vehicles due to concerns about charging accessibility. Another reason is that charging an electric vehicle typically takes longer than refueling a conventional vehicle. The slow charging speed, especially for conventional charging stations, can be a deterrent for potential electric vehicle owners in Bangladesh.[57] This is especially relevant in a country with frequent power outages or an unreliable electricity supply. The perception of longer charging times and the associated inconvenience may discourage people from switching to electric vehicles.

Moreover, the lack of knowledge and consciousness about electric vehicles and their infrastructure is another factor affecting adoption.[4] Many potential buyers may not be familiar with the benefits, charging requirements, or availability of charging infrastructure for electric vehicles. This lack of awareness can create uncertainty and hesitation among consumers, leading to a slower adoption rate.

Initiatives to raise awareness and educate the public are essential in tackling this issue and fostering comprehension of electric vehicle infrastructure. Furthermore, creating an extensive charging infrastructure network demands substantial investment encompassing the installation of charging stations, enhancement of electrical infrastructure and integration with the grid. In nations undergoing development like Bangladesh, the expense of establishing such infrastructure could pose a significant obstacle. Factors such as constrained financial resources, competing priorities and the necessity for collaborative efforts between private and public sectors might impede the swift progression of charging infrastructure.

Additionally, researchers have found analogous findings that stated that service after-sales factors have an insignificant effect on Electric Vehicle Adoption (EVA).[58-60] Service after-sales factors, including the availability and quality of maintenance and repair services for electric vehicles, can significantly impact Electric Vehicle Adoption (EVA) in any country. However, there are several reasons why these factors may currently have an insignificant effect on EVA in Bangladesh.

However, electric vehicles are still in the initial stage of adoption in Bangladesh with a relatively small number of electric vehicles on the roads.[61] The limited market penetration means fewer electric vehicles require maintenance and repair services. Consequently, the demand for specialized service centers and technicians may be low, leading to a lack of investment and development in this area. Another reason is that customer perception and awareness play a crucial role in identifying the significance of service after-sales factors.[62] In Bangladesh, where electric vehicle adoption is still limited, the general public may have little knowledge and understanding of electric vehicle maintenance requirements and service options. This lack of awareness may result in a reduced emphasis on service after-sales factors during the decision-making process for potential electric vehicle buyers. A study by the Bangladesh University of Engineering and Technology in 2020 found that the lack of awareness about the benefits of after-sales service is a key barrier to the adoption of electric vehicles in Bangladesh. The study found that many people are unaware of the potential savings that can be achieved by having their electric vehicles serviced regularly. In addition, Electric vehicles have different components and systems unlike traditional internal combustion engine vehicles. This requires specialized knowledge and skills to diagnose and repair electric vehicle-specific issues. Bangladesh may have a shortage of trained technicians with electric vehicle maintenance and repair expertise. This shortage can affect the availability and quality of service after sales, potentially discouraging potential buyers from adopting electric vehicles. Moreover, the availability of service centers and spare parts is often dependent on the support provided by electric vehicle manufacturers.[63] In countries where electric vehicle adoption is relatively low, manufacturers may be hesitant to invest in establishing a robust service network. Without manufacturer support, it becomes challenging to ensure a comprehensive service after-sales experience for electric vehicle owners in respect to accessibility and quality of maintenance and repair services.

From the above discussion, we can conclude that affordability and insufficient infrastructure play a significant role in the adoption

of electric vehicles in Bangladesh. On the other hand, service after sales plays an insignificant role.

Addressing the affordability and insufficient infrastructure factors connected with EV adoption in Bangladesh requires a multi-faceted approach. By addressing these factors, the affordability of EVs and the inadequate infrastructure can be improved, thereby facilitating their broader adoption in Bangladesh.

Implications

Practical Implications

Practically, this study has a significant contribution towards a sustainable transportation system as the adoption of EVs can aid to the development of a sustainable transportation system. By reducing dependence on fossil fuels, EVs help diversify the energy mix in the transportation sector and reduce the environmental impact of transportation activities.[64] The study's insights can inform policymakers and transportation planners in Bangladesh about the factors influencing EV adoption, enabling them to develop strategies and infrastructure plans that facilitate the transition to a sustainable transportation system. The study's findings can contribute to raising environmental awareness and promoting behavior change among consumers in Bangladesh. Individuals may become more conscious of the effects of their transportation choices on their surroundings if they understand the determinants that affect the adoption of EV.[65] The study can help in designing targeted awareness campaigns and educational programs that highlight the benefits of EVs and encourage individuals to make greener transportation choices, supporting sustainable development and a green environment.

Likewise, the study will help identify specific market segments within Bangladesh that are more likely to adopt EVs. This information can assist manufacturers and marketers in targeting their products and marketing campaigns towards these segments, tailoring messaging and features to meet their specific needs and preferences. For example, if urban dwellers are found to be more receptive to EVs, marketing efforts can be focused on promoting the benefits of EVs in urban environments.[66] In addition, the study will also guide product development strategies for EV manufacturers. By understanding the factors influencing EV adoption in Bangladesh, manufacturers can design EV models that align with the preferences and requirements of the local market. This may include developing EVs with longer driving ranges, affordable pricing and features that address the unique challenges faced by consumers in Bangladesh, such as hot and humid climates. Moreover, the study provides insights into the factors affecting the adoption of EVs related to charging infrastructure. This insight can guide the planning and development of charging infrastructure networks in Bangladesh. Stakeholders can identify the areas where charging stations are most needed, determine the optimal number and best locations for charging stations and consider the types of charging options (fast charging, slow charging, etc.,) that would fit the needs of EV owners.

The study's outcomes can enlighten policymakers in Bangladesh about the factors influencing EV adoption. Policymakers can use this information to formulate and revise policies that support and promote EV adoption. For instance, if the study reveals that financial incentives are crucial for EV adoption, policymakers can design effective incentive programs, such as tax incentives, subsidies, or grants, to make EVs more affordable for consumers. The study marks the importance of public awareness and education in promoting EV adoption. Practical implications include the need for awareness campaigns and educational programs that provide accurate and unbiased information about EVs. These efforts can help dispel myths, address misconceptions and increase consumer knowledge and acceptance of EV technology in Bangladesh.

By considering these practical implications, stakeholders in Bangladesh can take targeted actions to overcome barriers to EV adoption, foster a supportive ecosystem and facilitate the transition towards a sustainable and low-carbon transportation system. In summary, by identifying the factors affecting EV adoption in Bangladesh, this research offers insightful details for policymakers, industry stakeholders and individuals to drive sustainable development and create a greener environment. The adoption of EVs can contribute to reduced emissions, energy efficiency, renewable energy integration, a sustainable transportation system,[67,68] circular economy practices and environmental awareness, all of which are essential components of sustainable development and a green future.

Managerial Implications

The study presents insightful facts into the factors affecting EV adoption in Bangladesh. Managers can use this information to conduct a comprehensive market analysis, understanding the current state of EV adoption, consumer preferences and barriers to entry. This analysis can guide managerial decision-making, such as product development, marketing strategies and resource allocation. The study's findings can inform managers in the automotive industry about the specific features and attributes that are important to potential EV buyers in Bangladesh. This information can guide product planning and development processes, helping managers prioritize the design and development of EV models that address the specific needs and preferences of the local market. For example, if affordability is a key factor, managers can focus on developing cost-effective EV models with competitive pricing.[69] The study underscores the necessity of collaboration between diverse stakeholders in promoting EV adoption. Managers can explore partnership opportunities with government agencies, charging infrastructure providers, financial institutions and other relevant organizations. Collaborative efforts can lead to the development of charging

infrastructure networks, financial incentives and supportive policies that facilitate EV adoption.[70] Managers can take the lead in initiating and fostering such partnerships. Moreover, the study reveals that consumer awareness and education are vital for EV adoption. Managers can play a role in organizing training programs and workshops to enhance the knowledge and skills of their sales and service teams. Well-informed and trained staff can effectively communicate the benefits of EVs, address customer concerns and provide reliable after-sales support. This can positively impact the adoption rate by building consumer confidence in EV technology. The importance of long-term planning and strategy for EV adoption is highlighted in the study. Managers can incorporate the study's findings into their strategic planning processes, setting long-term goals and objectives related to EV market penetration. By aligning business strategies with the evolving EV landscape in Bangladesh, managers can position their organizations as leaders in the emerging market, gaining a competitive advantage.

In addition, this study also has a theoretical contribution based on TPB, which lies in identifying significant factors that influence EV adoption. Specifically, the findings indicate that insufficient infrastructure and affordability are significant factors affecting the adoption of EVs, while service after sales is not a significant factor. This adds to the body of current literature on EV adoption and provides valuable insights into the unique context of Bangladesh.

Limitations of the Study and Recommendations for Future Research

The limitations of a study on factors affecting the adoption of EVs in Bangladesh can vary depending on the specific research design and methodology employed. However, some common limitations exist, which are also reflected in this study. The small sample size of the study may limit the applicability of the results to the vast majority of EV adopters in Bangladesh. This could result in a potential bias or limited representation of different socio-economic groups, geographical regions, or specific demographics. The study does not fully consider Bangladesh's unique socio-cultural, economic and infrastructural contexts. The factors influencing EV adoption in Bangladesh could differ from those observed in other countries or regions, highlighting the need for context-specific research. Again, not every relevant determinant that affects EV adoption are taken into consideration in this study. Thus, there could be additional variables or interactions among factors that were not considered, leading to potential limitations in the study's findings.

It's important to note that these limitations are not exhaustive and will vary depending on the specific research design and execution. Researchers should address and acknowledge these limitations when conducting further studies on this topic. Moreover, researchers may consider a more extensive and diverse sample, in-depth analysis of specific factors, cross-cultural studies and economic and financial analysis for future studies that will support the development of more thorough understanding of factors influencing the widespread use of EVs in Bangladesh and provide guidance for setting up of policies and strategies aimed at promoting sustainable modes of transportation in the country.

CONCLUSION

This study examines factors that affect the adoption of EVs in Bangladesh. The findings of this study on EV adoption in Bangladesh shed light on broader implications for countries facing similar challenges. Insufficient infrastructure and affordability emerged as significant barriers to EV adoption, while service after-sales factors showed no significant effect. Inadequate infrastructure for EV charging remains a common obstacle globally.[71,72] Many countries lack a comprehensive charging network, hindering the widespread adoption of EVs.[73,74] Addressing this issue requires significant funding to be allocated to the infrastructure of charging, involving rapid charging technology, charging stations for the public and integration with renewable energy sources. Governments and private sector stakeholders need to collaborate to develop robust charging networks to encourage EV uptake. Affordability is still a major issue for potential EV buyers.[75,76] High upfront costs, limited availability of affordable EV models and concerns about battery replacement costs deter many consumers. Policymakers must implement measures to make EVs more financially accessible, such as subsidies, tax incentives and financing options.

Additionally, fostering competition among manufacturers can drive down prices and improve affordability. Moreover, the lack of significant influence from service after-sales factors suggests a potential area for optimization in EV markets.[77,78] While post-purchase service is essential for customer satisfaction and retention, it may not be a primary driver of initial adoption. However, ensuring reliable maintenance and support services is essential for building trust in EV technology and promoting long-term sustainability.

By understanding these factors, policymakers and stakeholders can formulate and implement effective strategies, policies and incentives that facilitate the widespread adoption of EVs,[67,79] leading to reduced emissions,[68] improved air quality, enhanced energy efficiency, renewable energy integration and sustainable urban development. The challenges faced in the adoption of Electric Vehicles (EVs) in Bangladesh are similar to those encountered by many other nations aiming to achieve Sustainable Development Goal 7 (SDG 7)-ensuring reliable, affordable and modern energy for all-and SDG 11-making cities and human settlements inclusive, safe, resilient and sustainable.[80,81] However, addressing infrastructure gaps, improving affordability and optimizing after-sales services are critical steps for accelerating EV adoption worldwide. Hence, collaborative efforts involving

governments, industry stakeholders and communities are necessary to overcome these barriers and transition towards a more sustainable transportation future.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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