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Understanding Electric Vehicle Adoption Intention in an Infrastructure-Constrained Context: The Roles of Perceived Charging Infrastructure Availability, Perceived Usefulness, and Perceived Electricity Reliability

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Abstract

This study examines the relationship between perceived charging infrastructure availability and electric vehicle (EV) adoption intention among private passenger vehicle users in Harare, Zimbabwe. It further explores whether the perceived usefulness statistically mediates this relationship and whether perceived electricity reliability moderates it. Data were collected through a cross-sectional survey of 298 private passenger vehicle users in Harare and analyzed using covariance-based structural equation modeling in AMOS. The results indicate that the perceived charging infrastructure availability is positively associated with both perceived usefulness and EV adoption intention, and perceived usefulness is strongly associated with EV adoption intention. The study also revealed that perceived usefulness mediates the association between perceived charging infrastructure availability and EV adoption intention. In addition, perceived electricity reliability significantly moderates the relationship between perceived charging infrastructure availability and EV adoption intention, highlighting the importance of electricity system conditions to consumer acceptance of electric mobility. This study contributes to the literature on EV adoption by integrating technology acceptance perspectives with perceived infrastructure availability and electricity system reliability within an emerging market context. Practically, the findings underscore the potential value of coordinated policy and industry strategies that combine charging infrastructure development, improvements in electricity system reliability, and consumer-focused communication to support the transition into electric mobility.

Keywords: complementary assets; electric vehicle adoption; perceived charging infrastructure availability; perceived usefulness; technology acceptance model; sustainable mobility

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1. Introduction

The global transition toward sustainable transportation has positioned electric vehicles (EVs) as a potentially important technological option for reducing greenhouse gas emissions, improving urban air quality, and decreasing dependence on fossil fuels [1]. In response, governments and industry stakeholders have increasingly invested in EV technologies and supporting infrastructure to accelerate the transition to low-carbon systems [2]. These efforts have been accompanied by substantial growth in EV adoption across many

developed countries. However, adoption remains uneven across regions, with many developing countries, particularly those in sub-Saharan Africa, experiencing relatively low levels of EV uptake [3]. This uneven development has stimulated growing scholarly interest in understanding the factors that facilitate or constrain consumers' intentions to adopt electric vehicles [4]. Among the factors identified in the literature, charging infrastructure has consistently emerged as a key factor associated with EV adoption [5]. Unlike conventional vehicles, which rely on relatively established fuel distribution networks, EVs depend on accessible and convenient charging facilities. Although the physical provision of charging facilities is important, consumers' subjective perceptions of their availability may also significantly influence their adoption intention [6]. Therefore, understanding these perceptions is particularly relevant in markets where charging networks remain limited or unevenly distributed.

Disparities in electric vehicle (EV) adoption are particularly evident across sub-Saharan Africa, where investments in EV infrastructure remains limited and varies considerably across countries [7]. Although research on EV adoption has expanded rapidly, much of the existing evidence has been generated in developed economies characterized by relatively mature charging infrastructure, reliable electricity systems, and supportive institutional environments [3]. Consequently, the applicability of findings from these contexts to developing economies remains uncertain. Many African cities present context conditions in which infrastructural limitations, electricity supply challenges, affordability constraints, and institutional capacity may be associated with consumer perceptions and EV adoption intentions in ways that differ from those observed in more developed markets. Accordingly, Ref. [8] emphasized the need for empirical research examining both infrastructural and behavioral determinants of EV adoption in the African contexts. Moreover, previous studies have predominantly examined the direct association between charging infrastructure and EV adoption, with comparatively less attention given to the cognitive and contextual factors that may account for variation in this association [9,10]. In particular, limited attention has been given to the role of perceived usefulness as a potential mediating factor and perceived charging infrastructure availability and EV adoption intention.

Zimbabwe provides a relevant empirical context for examining these relationships. The transition toward electric mobility has received increasing policy attention, with the government introducing initiatives intended to promote EV adoption [11]. These measures include reducing the import duty on fully electric vehicles from 40% to 25% under Statutory Instrument 35 of 2025 and providing duty rebates on equipment used to establish solar-powered charging stations. Such measures reflect recent policy efforts to support sustainable transportation and reduce dependence on fossil fuels. Nevertheless, EV adoption in Zimbabwe remains limited and is constrained by several structural challenges, including inadequate charging infrastructure, unreliable electricity supply, high vehicle acquisition costs, limited access to vehicle financing, shortages of specialized technical expertise, and constrained availability of EV-specific spare parts [12]. These conditions distinguish the Zimbabwe context from markets with more mature electric mobility ecosystems and highlight the need for empirical evidence that accounts for the country's specific infrastructural and energy-system conditions. In particular, understanding how consumers' perceptions of charging infrastructure availability and electricity reliability are associated with EV adoption intention is important for contextualizing technology acceptance in Zimbabwe.

The Zimbabwean context also raises an important theoretical question regarding how consumers' perceptions of infrastructure are associated with their intentions to adopt EVs. The Technology Acceptance Model (TAM) identifies perceived usefulness as a central construct in explaining technology-use intentions. However, limited empirical research has examined whether perceived usefulness statistically mediates association between perceived

charging infrastructure availability and EV adoption intention, particularly in developing-country contexts. In addition, although electricity supply reliability represents an important practical consideration for EV users, limited attention has been given to whether perceived electricity reliability moderates the association between perceived charging infrastructure availability and EV adoption intention. In contexts characterized by unreliable electricity supply, perceptions of charging infrastructure availability may therefore be associated with EV adoption intention differently depending on consumers' perceptions of electricity reliability. Examining these relationships can provide a more comprehensive understanding of EV adoption intention under infrastructure-constrained conditions. Accordingly, this study examines the direct association between perceived charging infrastructure availability and EV adoption intention, assesses the mediating role of perceived usefulness, and examines the moderating role of perceived electricity reliability. The study therefore addresses the following research questions:

RQ1: To what extent is perceived charging infrastructure availability associated with perceived usefulness?

RQ2: What is the relationship between perceived usefulness and electric vehicle adoption intention?

RQ3: What is the relationship between perceived charging infrastructure availability and electric vehicle adoption intention?

RQ4: Does perceived usefulness mediate the association between perceived charging infrastructure availability and electric vehicle adoption intention?

RQ5: Does perceived electricity reliability moderate the relationship between perceived charging infrastructure availability and electric vehicle adoption intention?

This study contributes to the electric vehicle adoption literature by empirically examining how infrastructure-related perceptions are associated with adoption intention in a developing country context characterized by infrastructure constraints. Specifically, the study applies the Technology Acceptance Model (TAM) to examine the association between perceived charging infrastructure availability and EV adoption intention, while also assessing the mediating role of perceived usefulness and the moderating role of perceived electricity reliability. By providing evidence from Zimbabwe, the study responds to the limited representation of sub-Saharan African contexts in the EV adoption research and provides context-specific evidence on technology acceptance perspectives within conditions of infrastructure and energy-system uncertainty. The findings provide a context-sensitive understanding of EV adoption behavior and highlight the importance of considering complementary infrastructure and electricity-system conditions when applying technology acceptance perspectives to emerging electricity-mobility markets.

2. Literature Review

2.1. Electric Vehicle Adoption

The adoption of electric vehicles (EVs) has attracted considerable attention given their potential contribution to sustainable transport transitions. EVs have the potential to reduce transport-related carbon emissions, dependence on fossil fuels and urban air pollution [13]. However, their diffusion remains constrained by a range of economic, infrastructural, technological, and institutional barriers. Previous research identifies inadequate charging infrastructure, high purchase costs, and insufficient supportive policies and legislation as important barriers to EV adoption [3]. These challenges are particularly relevant in developing countries, where limited consumer knowledge, high upfront costs, inadequate policy incentives, and underdeveloped supporting infrastructure may constrain the transition to electric mobility [14]. In this regard, EV adoption can be understood as reflecting the interaction of economic, psychological and contextual factors [15]. These

factors are particularly relevant to understanding consumers' intentions to adopt EVs in contexts where the infrastructure and institutional conditions supporting electric mobility remain underdeveloped.

2.2. Perceived Charging Infrastructure Availability

Perceived Charging Infrastructure Availability (PCIA) refers to an individual's overall perception of whether EV charging infrastructure is sufficiently available and practically accessible for EV use. Previous research identified charging infrastructure as an important factor associated with EV adoption [15]. PCIA therefore extends beyond the mere physical presence of charging stations to include their spatial distribution, accessibility, adequacy, reliability, and convenience of use. These attributes contribute to whether users perceive charging infrastructure as sufficiently available to meet their charging needs. Accordingly, in this study, these indicators are treated as reflective manifestations of an underlying perception of charging infrastructure availability and adequacy rather than separate dimensions of the construct. Concerns about running out of battery power before a destination, commonly referred to as range anxiety, represent another consideration associated with perceptions of charging availability [16]. Although such concerns may be addressed partly through increased knowledge and education about EVs, Ref. [17] reported that range anxiety is significantly associated with consumer decision-making regarding EV purchasing. Adequate, accessible, reliable and conveniently located charging infrastructure may therefore be associated with lower perceived charging-related constraints and greater perceived practical attractiveness of EV use.

2.3. Perceived Usefulness

According to [18], perceived usefulness is an important factor associated with individuals' intention to use new technologies. Perceived usefulness refers to an individual's perception that using a particular product or technology will enhance performance or facilitate the achievement of desired outcomes [19]. In the context of EVs, perceive usefulness may be based on anticipated benefits such as lower operating costs, greater energy efficiency, environmental benefits, and increased comfort and convenience. Consumers may therefore express stronger intentions to adopt EVs when they perceive advantages over conventional Internal Combustion Engine (ICE) vehicles [20]. Perceived usefulness may also be associated with contextual factors, including access to supporting infrastructure, government support, prior experience with the technology, and access to relevant information. In this study, availability of charging infrastructure is particularly relevant because perceptions of accessible and adequate charging facilities may be associated with consumers' evaluations of the practical usefulness of EVs.

2.4. Perceived Electricity Reliability

Perceived electricity reliability refers to consumers' perceptions of the consistency and dependability of the electricity supply for routine EV charging [21]. It captures consumers' confidence that electricity will be available, stable, and sufficient when charging is required. Unlike objective measures of electricity reliability, which are typically based on technical indicators such as outage frequency, duration, and grid performance metrics, perceived electricity reliability reflects users' subjective experiences, expectations, and beliefs regarding the quality and dependability of electricity provision [22]. Thus, the construct captures how consumers perceive the reliability of the electricity supply rather than its objective measured technical performance.

2.5. Electric Vehicle Adoption Intention

Behavioral intention is generally regarded as a proximal predictor of actual technology use and technology-related decision-making. In the context of EVs, adoption intention refers to an individual's stated willingness or likelihood of purchasing or using an EV in the future. EV adoption intention is associated with a range of cognitive, attitudinal, and contextual factors, including perceived usefulness, perceived ease of use, environmental concerns, cost considerations, and infrastructure readiness [23]. Existing studies suggest that positive environmental attitudes alone may not translate into strong EV adoption intention when significant structural and contextual barriers remain [24]. This highlights the importance of considering both psychological factors and the structural conditions that support electric mobility when examining EV adoption. In this study, perceived charging infrastructure availability and perceived electricity reliability represent important contextual factors, while perceived usefulness represents a key cognitive factor associated with EV adoption intention.

2.6. Theoretical Foundation

Electric vehicle (EV) adoption has been examined from various theoretical perspectives, including the Theory of Planned Behavior [25], Diffusion of Innovation Theory [26], the Unified Theory of Acceptance and Use of Technology [18], and the Value–Belief–Norm framework [27]. These perspectives highlight the roles of attitudes, social influence, facilitating conditions, environmental values, and innovation characteristics in shaping adoption intention. This study adopts the Technology Acceptance Model (TAM) [19] as its primary theoretical lens because TAM provides a parsimonious model for explaining how external factors shape technology adoption acceptance through users' cognitive evaluations. Specifically, the TAM is appropriate for examining how perceptions of charging infrastructure are associated with EV adoption intention through perceived usefulness. The original TAM identifies perceived usefulness and perceived ease of use (PEOU) as central determinants of technology acceptance. Perceived usefulness refers to the extent to which individuals believe that using a technology will enhance their performance, whereas perceived ease of use reflects the extent to which they believe that using the technology requires little effort [19].

Although PU and PEOU constitute the core cognitive determinants in the original TAM, the present study does not seek to test the complete original TAM. Instead, it adopts a focused application of the model centred on PU because the research question concerns whether perceptions of charging infrastructure availability are associated with EV adoption intention through evaluations of the practical usefulness of EVs. This focus is particularly relevant to EVs because their use depends on access to complementary charging and electricity infrastructure. PU therefore provides the most direct cognitive link between the perceived availability of charging infrastructure and consumers' assessments of the practical value of EV adoption. In contrast, PEOU concerns the effort associated with using a technology and does not directly capture the availability or reliability of the infrastructure required to operate an EV. Its exclusion reflects the specific theoretical scope of this study and should not be interpreted as suggesting that PEOU is unimportant in the broader TAM literature or in EV adoption.

In the EV context, perceived usefulness reflects consumers' evaluations of the economic and functional benefits associated with EV ownership, including lower operating costs and improved energy [28]. The availability of complementary infrastructure for practical EV use may shape these evaluations. Unlike many technologies that can be used largely independently of supporting infrastructure, EV adoption depends on charging infrastructure and the electrical networks that supply power to it. Consequently, perceptions of

charging infrastructure availability may form part of consumers' evaluations of the practical usefulness of EVs. Although the TAM provides the primary theoretical foundation for PCIA-PU-EVI relationships, this study focuses on perceived usefulness because the research context places particular emphasis on the practical conditions required for EV use. Perceived electricity reliability is incorporated as a contextual moderator to examine whether the relationship between perceived charging infrastructure availability and EV adoption intention varies according to consumers' perceptions of electricity supply reliability. The application of the TAM in this study therefore retains the model's core cognitive mechanism while situating technology acceptance within the infrastructural conditions relevant to EV use. The framework is complemented by the sociotechnical systems perspective [29] and the logic of complementary assets [30] to explain why the relationship between perceived charging infrastructure availability and EV adoption intention may depend on perceptions of electricity reliability.

2.7. Research Model and Hypothesis Development

2.7.1. Perceived Charging Infrastructure Availability and Perceived Usefulness

Perceived Charging Infrastructure Availability (PCIA) refers to the extent to which consumers perceive EV charging facilities as sufficiently available, accessible, reliable, and geographically distributed to support routine travel [28]. Perceptions of charging infrastructure availability may be associated with consumers' perception of EVs as practical and viable mobility options. Conversely, perceptions of inadequate charging infrastructure may be associated with greater range anxiety, perceived inconvenience, and lower confidence in the practical usability of EVs, particularly in markets with limited or emerging charging networks [17]. When consumers perceive the charging infrastructure as sufficiently available and accessible, they may have greater confidence in the practical usability of EVs, which may correspond with more favourable evaluation of their usefulness [31]. Conversely, perception of inadequate infrastructure may be associated with less favourable evaluations of EV practicality because anticipated difficulties in accessing charging facilities may diminish the perceived benefits of EV ownership [32]. Therefore, the following hypothesis is proposed:

Hypothesis 1. *Perceived charging infrastructure availability is positively associated with perceived usefulness.*

2.7.2. Perceived Usefulness and EV Adoption Intention

Within the Technology Acceptance Model (TAM), perceived usefulness refers to the extent to which individuals believe that using a technology will enhance their performance or provide valuable benefits [19]. In the context of EVs, this construct reflects consumers' perceptions of the extent to which EVs can meet their mobility needs through benefits such as improved energy efficiency, lower operating costs, and suitability for everyday transportation. Consumers who perceive EVs as functionally and economically beneficial may report stronger intentions to adopt them. Empirical evidence identifies perceived usefulness as an important factor associated with technology adoption intention, as individuals tend to adopt technologies that they perceive as beneficial and valuable [33]. This relationship may be particularly relevant in developing-country contexts, where instrumental considerations such as affordability, operational practicality, and the capacity of new technologies to address everyday mobility needs may be especially important in technology adoption decisions [34]. Therefore, this study proposes the following hypothesis:

Hypothesis 2. *Perceived usefulness is positively associated with EV adoption intention.*

2.7.3. Perceived Charging Infrastructure Availability and EV Adoption Intention

Perceived charging infrastructure availability is expected to be positively associated with EV adoption because accessible, and reliable charging facilities can enhance consumers' perceptions of the practicality and feasibility of EV ownership. Ref. [35] reported that perceived charging infrastructure was positively associated with EV adoption intention. This relationship can be explained theoretically by the concept of facilitating conditions, which suggests that individuals are more likely to adopt a technology when they perceive that the resources and infrastructure necessary for its use are available. This is also consistent with perceived behavioral control, as the availability of charging infrastructure may strengthen consumers' confidence in their ability to use EVs conveniently and effectively. Conversely, inadequate charging infrastructure may increase range anxiety, perceived inconvenience, and uncertainty regarding the everyday usability of EVs, thereby weakening adoption intentions [36]. Well-developed and reliable charging networks may therefore strengthen consumers' perceptions of the practical feasibility of EV ownership and increase their readiness to adopt EVs [37]. Therefore, this study proposes the following hypothesis:

Hypothesis 3. *Perceived charging infrastructure availability is positively associated with EV adoption intention.*

2.7.4. Perceived Usefulness as a Mediator

Within the TAM, external conditions are theorized to be related to technology acceptance through users' cognitive evaluations of the technology, particularly its perceived usefulness [19]. Perceived usefulness therefore represents a cognitive pathway through which contextual conditions may be associated with technology adoption intention. In the context of EVs, perceived charging infrastructure availability represents an important external condition because consumers may evaluate the practicality and value of EVs partly in relation to the infrastructure required for their use [38]. Although perceived usefulness has consistently been identified as an important factor associated with technology adoption intention [33], less attention has been given to its potential role as a mediating construct linking perceptions of charging infrastructure availability with EV adoption intention. Examining this relationship can therefore extend the application of TAM by assessing whether perceived usefulness statistically mediates the association between perceived charging infrastructure availability and EV adoption intention.

Unlike many technologies whose usefulness can be evaluated largely through their intrinsic features, EVs depend on complementary charging infrastructure to deliver their expected functional, economic, and environmental benefits [39]. Consequently, perceptions of accessible, reliable, and sufficient charging infrastructure may be associated with more favorable evaluations of EV practicality, convenience, and overall value. Consumers who perceive charging infrastructure availability as capable of supporting their mobility needs may therefore be more likely to regard EVs as useful and viable transportation options, which may, in turn, be associated with stronger adoption intentions [40]. Perceived usefulness thus represents a plausible cognitive pathway linking perceived charging infrastructure availability with EV adoption intention. Therefore, this study proposes the following hypothesis:

Hypothesis 4. *Perceived usefulness mediates the relationship between perceived charging infrastructure availability and electric vehicle adoption intention.*

2.7.5. Perceived Electricity Reliability as a Moderator

Electric vehicle (EV) adoption is embedded within a sociotechnical system in which vehicles, charging infrastructure, and electricity networks function as interconnected components rather than independent technological elements [41]. From a sociotechnical systems perspective, the adoption and practical use of a technology are shaped partly by the compatibility and functioning of the wider technical infrastructure within which it is embedded [42]. Accordingly, the perceived charging infrastructure availability may not be sufficient to generate confidence in EV use when the electricity system required to operate that infrastructure is perceived as unreliable. This argument is further supported by the complementary assets perspective [30]. Charging infrastructure represents an enabling asset for EV use, whereas a reliable electricity supply constitutes a complementary infrastructural condition that allows charging facilities to perform their intended function [43]. Consequently, consumers may evaluate charging infrastructure together with the reliability of the electricity that supports it. Perceived charging infrastructure availability is therefore expected to be more strongly associated with EV adoption intention when consumers also perceive the electricity supply as sufficiently reliable to support regular charging.

Perceived electricity reliability is thus theorized as a boundary condition of the relationship between perceived charging infrastructure availability and EV adoption intention. When electricity reliability is perceived to be high, consumers may regard available charging infrastructure as a more dependable component of the wider mobility–energy system, strengthening the positive association between charging infrastructure availability and EV adoption intention. Conversely, when electricity reliability is perceived to be low, anticipated interruptions and uncertainty regarding the ability to charge an EV may weaken the practical significance of the available charging infrastructure. The positive relationship between charging infrastructure availability and EV adoption intention is therefore expected to be stronger under conditions of higher perceived electricity reliability. This theoretical argument is particularly relevant in developing countries, where infrastructure-dependent technologies may be evaluated in relation to the reliability of interconnected technical systems. Accordingly, the sociotechnical systems perspective, complemented by the logic of complementary assets, provides a theoretical basis for expecting perceived electricity reliability to moderate the relationship between perceived charging infrastructure availability and EV adoption intention. Thus, this study proposes the following hypothesis:

Hypothesis 5. *Perceived electricity reliability moderates the association between perceived charging infrastructure availability and EV adoption intention such that the association is stronger when perceived electricity reliability is high.*

2.8. Research Model

Drawing on the TAM, this study proposes a conditional process model in which perceived charging infrastructure availability influences electric vehicle (EV) adoption intention both directly and indirectly through perceived usefulness. Consistent with the logic of complimentary assets, EVs are infrastructure-dependent technologies whose practical value depends partly on the availability of complementary charging infrastructure. Accordingly, consumers' perceptions of charging infrastructure availability are expected to shape their evaluation of the usefulness of EVs, which in turn influences adoption intentions. The model further proposes that perceived electricity reliability moderates the direct relationship between perceived charging infrastructure availability and EV adoption intention. This reflects the sociotechnical nature of EV adoption, whereby the usefulness of physical charging infrastructure is partly contingent on the reliability of the electricity system that supports its operation. The model integrates the TAM's cognitive mechanism

with the infrastructural interdependencies emphasized by the logic of complementary assets and the sociotechnical systems perspective. Age, gender, and income were included as control variables to account for demographic and socioeconomic differences in EV adoption intention. Income may influence EV affordability, whereas age and gender are associated with variations in technology acceptance and vehicle preferences. Controlling for these variables enables a more accurate estimation of the effects of focal constructs. The proposed relationships among the study variables are shown in Figure 1.

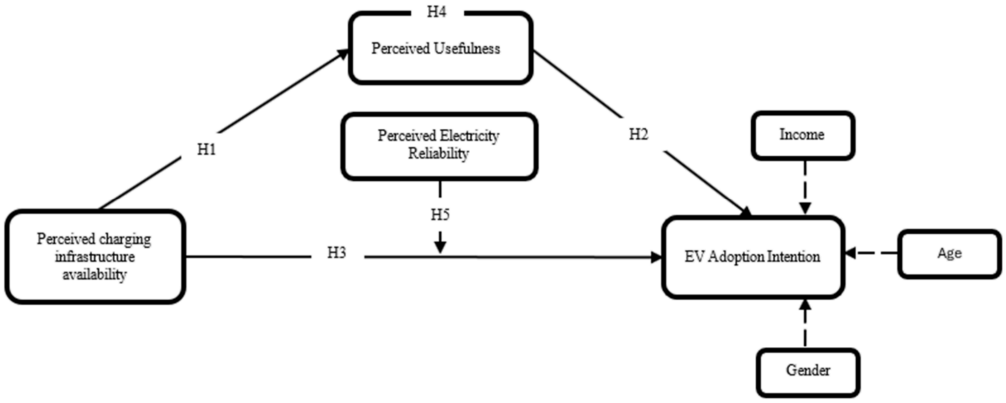


Figure 1. Research Model.

3. Methods

3.1. Study Design and Sample

This study employed a quantitative cross-sectional survey design to examine the relationships among perceived charging infrastructure availability, perceived usefulness, perceived electricity reliability, and electric vehicle (EV) adoption intention among private passenger vehicle users in Harare, Zimbabwe. Data were collected at a single point in time using a structured questionnaire administered in both paper-based and online formats. The target population comprised adults residing in Harare who owned or regularly used private passenger vehicles for personal purposes. Individuals whose primary vehicle use involved commercial passenger transportation, including taxi operators, ride-hailing drivers, public transport operators, and commercial fleet operators, were excluded because their vehicle adoption decisions may be influenced by operational, commercial, and regulatory considerations that differ from those affecting private vehicle users. Harare was selected as the study setting because of its status as Zimbabwe's principal economic and commercial centre and its importance as a major urban context for private vehicle use and mobility.

A nonprobability convenience sampling approach with purposive eligibility criteria was used. Participants were recruited from shopping centers, fuel stations, workplaces, and WhatsApp groups, which provided access to individuals likely to meet eligibility criteria. Participation was restricted to respondents who (i) were at least 18 years of age, (ii) resided in Harare, and (iii) owned or regularly used a private passenger vehicle for personal use. Before completing the questionnaire, the participants were informed of the study objectives, the voluntary nature of participation, and the confidentiality of their responses, and informed consent was obtained. Ethical approval was obtained from the Chinhoyi University of Technology Research Ethics Committee (Approval No. CUT/REC/2025/06). Data were collected between November 2025 and January 2026. Of the 350 questionnaires distributed, 312 were returned, representing a response rate of 89.1%. Following data screening, 14 responses were excluded because of substantial missing data or failure to meet the eligibility criteria. The final analytical sample consisted of 298 valid responses, representing 95.5% of the returned questionnaires and 85.1% of all questionnaires distributed.

Sample size adequacy was assessed via SEM-specific Monte Carlo simulation aligned with the proposed measurement and structural model. The simulation used the estimated structural parameters as population values, including PCIA → PU ($\beta = 0.520$), PU → EVI ($\beta = 0.630$), PCIA → EVI ($\beta = 0.280$), and the PCIA × PER → EVI interaction ($\beta = 0.160$), with indirect effect generated through the PCIA → PU → EVI pathway. Since the final estimated effects were used as population parameters, this analysis represents a post hoc power assessment rather than an independent a priori sample size justification. With 298 observations, $\alpha = 0.05$, 10,000 replications, and a complete-data assumption, the achieved power was approximately 0.97, 0.98, 0.92, 0.94, and 0.76 for the PCIA → PU, PU → EVI, PCIA → EVI, indirect, and interaction effects, respectively. These results indicate high simulated power for the specified direct and indirect effects; however, the interaction effect yielded a power estimate of 0.76, below the commonly used 0.80 benchmark, and should be interpreted with greater caution [44]. To reduce potential common variance, the questionnaires were designed with unambiguous wording, and the resulting data were subsequently assessed via a latent common method factor approach.

The demographic analysis indicated that (185) 62% of the respondents were male and (113) 38% were female, suggesting that the private passenger vehicle users in the sample were predominantly male. Regarding age, 48 (16.11%) respondents were aged 18–24 years, 91 (30.54%) were aged 25–34 years, 78 (26.17%) were aged 35–44 years, 51 (17.11%) were aged 45–54 years, and 30 (10.07%) were aged 55 years or older. In terms of income, (93) 31.21% of the respondents earned less than ZWG3000, (67) 22.48% earned between 3001 and ZWG5000, (75) 25.17% earned between ZWG5001 and ZWG10,000, (30) 10.07% earned between ZWG10,001 and ZWG50,000, and (33) 11.07% earned above ZWG50,001. Age, gender, and income were measured and included as exogenous control variables predicting electric vehicle adoption intention in the structural model.

3.2. Measurement

All the constructs were measured via multi-item scales adapted from other studies and modified to fit the purpose of this study. The structured questionnaire comprised five distinct sections. The first section assessed the demographic information of the respondents (such as gender, income, and age). Age was measured as a continuous variable in years, while gender was treated as a binary variable, with 0 representing female respondents and 1 representing male respondents. In addition, income was coded using ordered income categories, with higher numerical values representing higher income levels. The second section assessed perceived charging infrastructure availability (PCIA). The third section assessed perceived usefulness (PU), whereas the fourth and fifth sections assessed perceived electricity reliability (PER) and electric vehicle adoption intention (EVI), respectively. The questionnaire was administered in English. During data collection, clarification was provided where respondents had trouble understanding particular items, without altering their intended meaning. No translation or back-translation procedure was therefore undertaken.

A pilot study involving 34 randomly selected private passenger vehicle users was conducted to assess the clarity and comprehensibility of the measurement items and their preliminary reliability. The pilot study indicated that the items were clearly understood, and no items required modification or removal. Responses from the pilot study were excluded from the subsequent analyses to ensure that all analyses were based exclusively on the final study sample. Items measuring each construct were rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Table 1 presents the measurement items and their respective source references.

Table 1. Measurement Items.

Construct	Code	Measurement Items	Adapted From
Perceived Charging Infrastructure Availability (PCIA)	PCIA1	EV charging stations are easily accessible in Harare.	[3,9,28,45,46]
	PCIA2	Electric vehicle charging stations are sufficiently distributed across Harare.	
	PCIA3	EV charging infrastructure are available at locations where I need to charge an EV.	
	PCIA4	I easily find an EV charging facilities when I need one.	
	PCIA5	Harare has sufficient charging infrastructure to support the use of EVs.	
Perceived Usefulness (PU)	PU1	Electric vehicles can improve urban transport efficiency.	[18,19,47–49]
	PU2	Electric vehicles can reduce the overall transportation costs.	
	PU3	Electric vehicles would improve the convenience of daily travel.	
	PU4	Electric vehicles would reduce dependence on fossil fuels.	
	PU5	Overall, electric vehicles are beneficial for urban mobility.	
Electric Vehicle Adoption Intention (EVI)	EVI1	I intend to use electric vehicles in the future.	[4,5,14,15,18,19]
	EVI2	I am willing to adopt electric vehicles when possible.	
	EVI3	I will consider electric vehicles for my next purchase.	
	EVI4	I plan to use electric vehicles when they become available in the market.	
	EVI5	I expect to adopt an electric vehicle when suitable options become available to me.	
Perceived Electricity Reliability	PER1	The electricity supply in my area is sufficiently reliable to support regular EV charging.	[50,51]
	PER2	Power interruptions in my area are infrequent enough to allow dependable EV charging.	
	PER3	I am confident that the electricity supply in my area can consistently support future EV charging.	

3.3. Common Method Variance

Common method variance (CMV) was assessed using the latent common method factor (LCMF) approach in AMOS. An LCMF was specified alongside the substantive measurement model, with each observed indicator loading on both its designated substantive construct and the method factor. For model identification, one LCMF loading was fixed to 1.00 as the reference loading, while the remaining method-factor loadings were freely estimated. The LCMF was specified as orthogonal to the substantive latent constructs to isolate method-related variance from substantive construct variance. Given that the data were self-reported and obtained from a single source, CMV was considered a potential source of systematic measurement bias [52]. The baseline measurement model demonstrated acceptable fit ($\chi^2/df = 2.31$, CFI = 0.932, TLI = 0.924, RMSEA = 0.057). Following inclusion of the LCMF, model fit changed only marginally ($\chi^2/df = 2.27$, CFI = 0.936, TLI = 0.928, RMSEA = 0.056), and the substantive factor loadings showed minimal changes, with a maximum absolute change of 0.03. Collectively, these results provide no indication that CMV materially affected the substantive measurement relationships.

4. Results

The analyses were conducted using IBM Statistical Packages for Social Scientists (SPSS) Version 26 and IBM AMOS Version 22. Covariance-based structural equation modeling (CB-SEM) with maximum likelihood estimation was used to examine the hypothesised associations among the study constructs. Income, age and gender were included as control variables to account for potential sociodemographic differences in electric vehicle adoption intention. Before estimating the structural model, preliminary analyses were conducted to assess multicollinearity and common method variance. Multicollinearity among the predictors was assessed using Variance Inflation Factor (VIF) values, while common method variance was evaluated using the special statistical procedures. The analysis proceeded in two main stages. First, the measurement model was evaluated using Confirmatory Factor Analysis (CFA) to assess construct reliability, validity, and overall model fit. Second, the structural model was estimated to examine the hypothesised direct associations and the proposed mediating and moderating relationships.

4.1. Data Screening and Model Diagnostics

Before estimating the structural equation model, the data were screened for normality, multivariate outliers, and multicollinearity. Skewness values ranged from −1.21 to 0.84, whereas the kurtosis values ranged from −0.96 to 1.87, indicating acceptable univariate normality. The multivariate critical ratio for kurtosis was 2.41, which falls below the commonly applied absolute threshold of 5.0, providing support for approximate multivariate normality and the use of maximum likelihood estimation [53]. Multivariate outliers were assessed using the Mahalanobis distance, and no cases exceeded the critical χ^2 value at $p < 0.001$ (df = 18, critical $\chi^2 = 42.31$) [54]. All VIFs were below the recommended threshold of 3.3, suggesting that multicollinearity among the predictors was unlikely to materially affect the parameter estimates. Standardised residuals were subsequently examined to identify potential areas of local model misfit, with most values falling within ±2.58 [55]. Modification indices were also reviewed; however, no post hoc modifications were introduced solely to improve model fit. The final model was therefore retained on the basis of theoretical justification and parsimony [53].

4.2. Measurement Model Evaluation

The measurement model was evaluated in terms of model fit, indicator reliability, internal consistency reliability, and convergent validity. Model fit was assessed using the chi-square to degrees-of-freedom ratio (χ^2/df), comparative fit index (CFI), Tucker–Lewis index (TLI), and root mean square error of approximation (RMSEA). The results indicated an acceptable fit between the measurement model and the observed data. All standardized factor loadings were positive, statistically significant ($p < 0.001$), and exceeded the recommended threshold of 0.70, supporting indicator reliability [56]. The Cronbach's alpha and composite reliability (CR) values exceeded 0.70 for all constructs, supporting internal consistency reliability, while average variance extracted (AVE) exceeded 0.50 and convergent validity, respectively [56]. The standardized factor loadings (λ), critical ratio (C.R.), Cronbach's alpha, CR and AVE values are reported in Table 2.

Discriminant validity was assessed using the Fornell–Larcker criterion and the heterotrait–monotrait (HTMT) ratio. Under the Fornell–Larcker criterion, the square root of the average variance extracted (AVE) for each construct should exceed its correlations with the other constructs. As shown in Table 3, the square root of the AVE values on the diagonal exceeded the corresponding interconstruct correlations, supporting discriminant validity [57]. In addition, HTMT values ranged from 0.370 to 0.790, with all values below the conservative threshold of 0.85. These results provide further evidence that

PCIA, PU, EVI, and PER exhibit adequate discriminant validity and represent empirically distinguishable constructs.

Table 2. Reliability and Convergent Validity Assessment.

Construct	Item	VIF	CR	α	λ	C.R.	AVE
Perceived Charging Infrastructure Availability (PCIA)	PCIA1	1.46	0.908	0.88	0.79	9.62 ***	0.663
	PCIA2	2.38			0.83	10.41 ***	
	PCIA3	1.52			0.81	9.88 ***	
	PCIA4	2.41			0.86	11.02 ***	
	PCIA5	2.44			0.78	9.15 ***	
Perceived Usefulness (PU)	PU1	1.58	0.922	0.90	0.84	11.37 ***	0.703
	PU2	1.62			0.88	12.04 ***	
	PU3	2.49			0.82	10.18 ***	
	PU4	2.55			0.85	11.26 ***	
	PU5	1.60			0.80	9.73 ***	
Electric Vehicle Adoption Intention (EVI)	EVI1	1.41	0.935	0.92	0.86	12.55 ***	0.743
	EVI2	2.47			0.89	13.02 ***	
	EVI3	2.53			0.84	11.88 ***	
	EVI4	1.44			0.87	12.31 ***	
	EVI5	1.50			0.85	11.64 ***	
Perceived Electricity Reliability (PER)	PER1	2.11	0.823	0.81	0.80	9.28 ***	0.609
	PER2	1.89			0.78	10.11 ***	
	PER3	2.06			0.76	8.60 ***	

Note: λ = standardized factor loading; α = Cronbach's alpha; CR = composite reliability; AVE = average variance extracted; C.R.= critical ratio. *** $p < 0.001$.

Table 3. Discriminant Validity Fornell–Larcker Criterion and HTMT.

Construct	PCIA	PU	EVI	PER
Perceived Charging Infrastructure Availability (PCIA)	**0.815**	0.680	0.740	0.410
Perceived Usefulness (PU)	0.520	**0.838**	0.790	0.370
EV Adoption Intention (EVI)	0.550	0.620	**0.862**	0.320
Perceived Electricity Reliability (PER)	0.280	0.300	0.340	**0.780**

Note: Bold diagonal values represent the square roots of AVE. Values below the diagonal represent interconstruct correlations, whereas values above the diagonal represent HTMT ratios.

4.3. Structural Model Assessment

The structural model was evaluated using multiple goodness-of-fit indices, including absolute, incremental, and parsimonious fit measures. The results indicated an acceptable model fit: $\chi^2/df = 2.709$, GFI = 0.941, AGFI = 0.901, NFI = 0.920, TLI = 0.931, CFI = 0.951, and RMSEA = 0.053. The reported fit indices were within the recommended ranges, including thresholds (CFI and TLI ≥ 0.90; RMSEA ≤ 0.08). The model demonstrated acceptable fit across the reported indices, with CFI and TLI exceeding 0.90 and RMSEA below 0.08 [54]. The χ^2/df was also below 3.0, providing further support for an acceptable model fit. The GFI, AGFI, and NFI values were likewise above 0.90, although these indices were considered as supplementary rather than primary indicators of model adequacy. The model accounted for 27% of the variance in Perceived Usefulness (PU)

and 61% of the variance in electric vehicle adoption intention (EVI). Thus, the specified predictors accounted for a greater proportion of observed variance in EVI than in PU. The hypothesized direct associations were assessed using standardized path coefficients, critical ratios, and associated *p*-values, as reported in Table 4.

Table 4. Direct Relationships.

Hypothesis	Structural Path	β	C.R.	*p* Value	Decision
H1	PCIA → PU	0.520	9.84	<0.001	Supported
H2	PU → EVI	0.630	12.11	<0.001	Supported
H3	PCIA → EVI	0.270	5.40	<0.001	Supported
Control	Age → EVI	0.074	1.692	0.091	Not significant
Control	Gender → EVI	−0.058	−1.347	0.178	Not significant
Control	Income → EVI	0.116	2.384	0.017	Significant

The results in Table 4 show that all three direct hypotheses were supported. Perceived charging infrastructure availability (PCIA) was positively associated with perceived usefulness (PU) ($\beta = 0.520$, C.R. = 9.84, $p < 0.001$), supporting H1. The positive coefficient indicates that greater perceived availability of charging infrastructure is associated with higher perceived usefulness of EVs. The magnitude of $\beta = 0.520$ indicates a relatively strong positive standardized association, while $p < 0.001$ demonstrates that the relationship is statistically significant. Perceived usefulness (PU) was positively associated with electric vehicle adoption intention (EVI) ($\beta = 0.630$, C.R. = 12.11, $p < 0.001$), supporting H2. The $\beta = 0.63$ indicates a strong positive association between perceived usefulness and EV adoption intention, while the C.R. = 12.11 and $p < 0.001$ confirm that this relationship is statistically significant. PCIA was also positively associated with EVI ($\beta = 0.270$, C.R. = 5.40, $p < 0.001$), supporting H3. Although this association was weaker than the PU→ EVI relationship, the positive coefficient indicates that greater perceived charging infrastructure availability was associated with stronger EV adoption intention. The study also assessed the mediating role of perceived usefulness in the relationship between PCIA and the EVI via bias-corrected bootstrap procedures with 5000 resamples. An indirect effect was considered statistically significant when the 95% confidence interval did not include zero. The results are reported in Table 5.

Table 5. Mediating role of perceived usefulness.

Hypothesis	Effect Type	Structural Path	Standardized β	BootSE	95% Bootstrap CI	Decision
H4	Total Effect	PCIA → EVI	0.598	0.045	[0.520, 0.686]	Significant
	Direct Effect	PCIA → EVI (controlling PU)	0.270	0.050	[0.182, 0.378]	Significant
	Indirect Effect	PCIA → PU → EVI	0.328	0.039	[0.253, 0.409]	Significant

Note: β = standardized effect; BootSE = bootstrap standard error; CI = confidence interval. The total effect represents the overall association between PCIA and EVI, comprising the direct and indirect effects. The total effect is β = 0.598, comprising a direct effect of β = 0.270 and an indirect effect of β = 0.328.

As shown in Table 5, perceived usefulness (PU) statistically mediates the association between perceived charging infrastructure availability (PCIA) and electric vehicle adoption intention (EVI). The indirect association was positive and statistically significant (β = 0.328, BootSE = 0.039, 95% bias-corrected bootstrap CI [0.253, 0.409]), as the confidence interval did not include zero. This finding indicates that greater perceived availability of charging infrastructure is associated with stronger EV adoption intention, partly through enhanced perceptions of EV usefulness. The indirect effect is also consistent with the product of the

structural path coefficients in Table 4. Specifically, the product of the PCIA→ PU and PU → EVI coefficient is 0.520 × 0.630= 0.3276, which rounds to 0.328. However, the bootstrap estimate and its confidence interval provide the basis for statistical inference.

The direct association between the PCIA and the EVI remained positive and statistically significant accounting for PU (β = 0.270, BootSE =0.050, 95% bias-corrected bootstrap CI [0.182, 0.378]). The total effect was also statistically significant (β = 0.598 BootSE =0.045, 95% bias-corrected bootstrap CI [0.520, 0.686]). The estimated total effect is consistent with the combined direct and indirect effects. The coexistence of significant indirect and direct associations is consistent with partial statistical mediation, indicating that perceived usefulness constitutes an important pathway in the association between PCIA and EVI, while a significant direct association remains.

The interaction between perceived charging infrastructure availability (PCIA) and perceived electricity reliability (PER) was positive and statistically significant (β = 0.160, SE = 0.058, C.R. = 2.76, p = 0.006, 95% CI [0.046, 0.274]), supporting H5. The positive interaction indicates that the association between PCIA and electric vehicle adoption intention (EVI) varies systematically with perceived electricity reliability, with the estimated PCIA–EVI association increasing as PER increases. Thus, the relationship between charging infrastructure availability and EV adoption intention is contingent on the level of perceived electricity reliability. The moderation model extended the baseline structural model by adding PER and the PCIA × PER interaction term; consequently, the coefficients of the control variables differed slightly from those reported for the baseline structural model. The results are presented in Table 6.

Table 6. Moderation of the PCIA–EVI Relationship by PER.

Predictor	β	SE	C.R.	p-Value	95% CI	Decision
PCIA → EVI	0.270	0.050	5.40	<0.001	[0.172, 0.368]	Significant
PER → EVI	0.120	0.045	2.67	0.008	[0.032, 0.208]	Significant
PCIA × PER → EVI	0.160	0.058	2.76	0.006	[0.046, 0.274]	Supported (H5)
Age → EVI	0.070	0.044	1.59	0.112	[−0.016, 0.156]	Not significant
Gender → EVI	−0.060	0.043	−1.40	0.162	[−0.144, 0.024]	Not significant
Income → EVI	0.110	0.049	2.24	0.025	[0.014, 0.206]	Significant

Note: β = standardized coefficient; SE = standard error; C.R. = critical ratio; CI = confidence interval. PER should be mean-centred before creating the PCIA × PER interaction term. The interaction coefficient represents the moderation effect.

The conditional effect of PCIA on EVI increased from β = 0.110 at low PER to β = 0.270 at the mean level of PER and β = 0.430 at high PER. Although the conditional effect at low PER was not statistically significant (p = 0.072), whereas the effects at mean and high PER were statistically significant ($p < 0.001$), differences in statistical significance across these levels should not be interpreted as evidence that the conditional effects themselves differ significantly. Rather, the significant PCIA × PER interaction (β = 0.160, p = 0.006) provides evidence that the association between PCIA and EVI varies systematically with perceived electricity reliability. Thus, higher levels of PER were associated with progressively larger estimated PCIA–EVI coefficients. The results are presented in Table 7.

The findings suggest that perceived electricity reliability moderates the association between charging infrastructure availability and EV adoption intention. In particular, the association is not statistically distinguishable from zero when perceived electricity reliability is relatively low, whereas it becomes increasingly positive as perceived electricity reliability increases. This pattern suggests that the perceived availability of charging infrastructure may be more strongly associated with EV adoption intention when users also perceive the electricity supply as sufficiently reliable. Figure 2 provides a graphical representation of this interaction.

Table 7. Conditional Effects of PCIA on EVI at Different Levels of PER.

PER Level	Conditional Effect of PCIA on EVI (β)	S.E	C.R.	*p* Value	95% CI	Decision
Low PER (−1 SD)	0.110	0.061	1.80	0.072	[−0.010, 0.229]	Not Significant
Mean PER	0.270	0.050	5.40	<0.001	[0.172, 0.368]	Significant
High PER (+1 SD)	0.430	0.061	7.05	<0.001	[0.310, 0.550]	Significant

Note: PER was mean-centred before creating the interaction term. Conditional effects were evaluated at the mean and ±1 SD of PER. The conditional effects were 0.110, 0.270, and 0.430 at low, mean, and high PER, respectively.

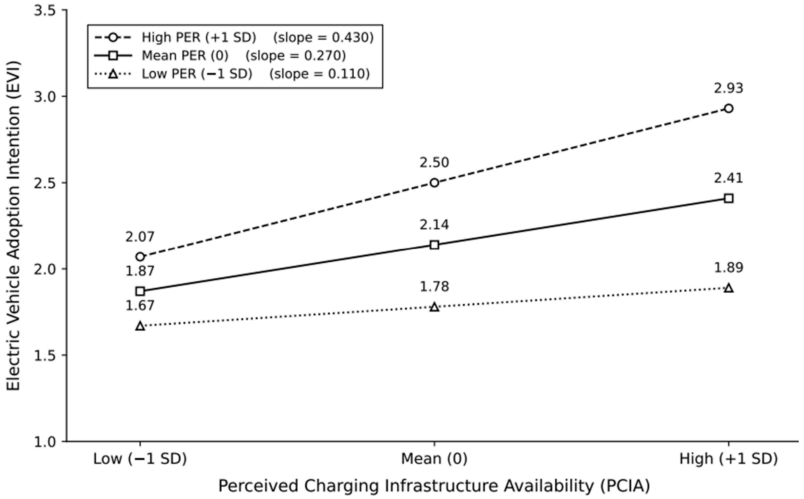


Figure 2. Moderating role of PER on the relationship between PCIA and EVI.

As illustrated in Figure 2, the slope for high PER is steeper than that for low PER, indicating that the positive relationship between PCIA and EVI is perceived to be stronger when electricity reliability is perceived to be greater. These findings position PER as an important contextual boundary condition in the EV adoption process. In infrastructure-constrained contexts such as Zimbabwe, consumers may not evaluate charging infrastructure independently from the energy system required to operate it. Thus, PCIA may be more strongly associated with the EVI when consumers perceive the electricity supply as sufficiently reliable to support regular vehicle charging.

5. Discussion and Implications

5.1. Discussion of the Key Findings

This study examined the relationships among Perceived Charging Infrastructure Availability (PCIA), Perceived Usefulness (PU), Perceived Electricity Reliability (PER), and electric vehicle adoption intention (EVI) among private passenger vehicle users in Harare, Zimbabwe. The findings indicate that EV adoption intention is associated not only with evaluations of the vehicle itself but also with perceptions of the infrastructure and energy conditions required for its practical use. Specifically, the PCIA was positively associated with both PU and EVI, while PU statistically partially mediated the association between the PCIA and the EVI. In addition, PER significantly moderated the association between PCIA and EVI, indicating that the strength of this relationship varied according to consumers' perceptions of electricity reliability. Collectively, these findings suggest that, in the Harare context, technology acceptance of infrastructure-dependent innovations may involve both cognitive evaluations of the technology and perceptions of the contextual conditions that support its practical use.

The positive association between PCIA and PU ($\beta = 0.520$, $p < 0.001$) supports the TAM proposition that external conditions can shape perceived usefulness and, consequently, technology acceptance [18,19]. The findings also illustrate the contextual relevance of the TAM in the EV domain. Unlike technologies whose usefulness can be evaluated largely through their intrinsic capabilities, the use of EVs depends on complementary infrastructure that supports charging and continued vehicle operation. Accordingly, consumers may incorporate perceptions of charging availability into their assessment of whether EVs represent a practical and valuable mobility option. This mechanism may be particularly salient in Harare's emerging EV market, where charging infrastructure remains limited and where electricity reliability is an important consideration in technology use. In contrast, in mature EV markets such as China and Europe, where charging networks are more established and electricity is more stable, infrastructure availability may operate as a background enabling condition [58,59]. Conversely, in infrastructure-constrained contexts, charging availability may become a salient consideration in perceptions of adoption feasibility because consumers must consider whether broader mobility and energy ecosystems can support vehicle use [60]. The findings therefore suggest that charging infrastructure represents not only an enabling condition but also a component of the perceived value proposition of EVs.

The strong association between PU and the EVI ($\beta = 0.630$, $p < 0.001$) reinforces the central TAM proposition that favorable technology evaluations are important predictors of behavioral intention. In the EV context, however, perceived usefulness may extend beyond conventional assessments of technological performance. For private vehicle users in Harare, perceived usefulness may encompass the extent to which EVs are regarded as dependable, convenient, and economically viable within existing infrastructural conditions. The significant indirect effect of PCIA on EVI through PU ($\beta = 0.328$, 95% CI [0.253, 0.409]) alongside the remaining direct effect of PCIA on EVI ($\beta = 0.270$, 95% CI [0.182, 0.378]) is consistent with partial statistical mediation. This suggests that the association between PCIA and EVI is partly accounted for by PU while a significant direct association between PCIA and EVI remains after accounting for PU. This finding is theoretically meaningful because it indicates that PU represents an important explanatory mechanism without fully accounting for the relationship between the PCIA and the EVI. The remaining direct relationship may reflect other considerations associated with perceived ownership practicality and future usability, although these mechanisms were not directly examined in this study.

The direct association between PCIA and the EVI ($\beta = 0.270$, $p < 0.001$) is also theoretically plausible. Although charging infrastructure represents a critical enabling condition, it is unlikely to be the sole consideration in EV adoption decisions. Other factors, including purchase affordability, battery range, maintenance costs, vehicle availability, policy incentives, and familiarity with EV technology, may also shape adoption intentions [4]. This finding therefore suggests that charging infrastructure is an important but not sufficient consideration in understanding EV adoption intention. More broadly, the finding is consistent with evidence from both developed and emerging markets, where EV adoption reflects the interaction of technological, economic, psychological, and institutional factors. The moderating effect of PER provides further evidence that the relationship between the PCIA and EVI is contingent upon the broader energy environment. The positive interaction effect between PCIA and PER ($\beta = 0.160$, S.E = 0.058, C.R. = 2.76, $p = 0.006$, 95%CI [0.046, 0.274]) indicates that the positive association between charging infrastructure availability and EV adoption intention becomes stronger as perceived electricity reliability increases. This suggests that consumers do not evaluate charging infrastructure in isolation; rather, they may consider whether the supporting electricity system can enable reliable, consistent and convenient EV operation.

This finding extends conventional EV adoption perspectives by highlighting electricity reliability as a potentially important contextual condition in infrastructure-constrained markets. In China and many European countries, where the electricity supply is generally more reliable than it is in many developing economies, research and policy have focused predominantly on charging density, incentives, and vehicle characteristics, with electricity reliability receiving comparatively limited attention as a determinant of EV adoption [58]. In contrast, in Zimbabwe and other sub-Saharan African contexts, electricity reliability represents an important contextual condition that may affect the practical value of charging infrastructure [11]. The availability of charging facilities may therefore have a limited influence on adoption intentions if consumers remain uncertain about the continuity of the electricity supply. This finding suggests the value of considering transport infrastructure and energy conditions jointly when examining EV adoption in infrastructure-constrained contexts. Overall, the study demonstrates that EV adoption in infrastructure-constrained contexts cannot be fully understood through technology perceptions alone. While the TAM provides a useful explanation of the cognitive mechanisms underlying adoption intention, its application to infrastructure-dependent technologies may benefit from greater attention to the complementary systems that enable technology use. The findings therefore contribute to a more context-sensitive understanding of EV adoption by suggesting that charging infrastructure availability and electricity reliability are relevant components of the sociotechnical context within which consumers evaluate the feasibility and value of EV ownership.

5.2. Theoretical Implications

This study contributes to the EV adoption literature by extending the empirical application of the Technology Acceptance Model (TAM) to Harare, a context characterised by limited charging infrastructure and uncertainty in electricity supply. Rather than proposing a new theoretical extension of the TAM, the study examines how established TAM relationships are manifested within infrastructure and energy-system constraints. The positive associations between perceived usefulness, perceived charging infrastructure availability and EV adoption intention are consistent with established findings in the EV adoption literature and are therefore not presented as novel theoretical relationships. Instead, the principal theoretical contribution lies in identifying perceived electricity reliability as a contextual boundary condition of the association between perceived charging infrastructure availability and EV adoption intention. This finding suggests that the relationship between infrastructure availability perceptions and EV adoption intention may vary according to consumers' perceptions of electricity reliability.

The findings highlight the importance of contextualising technology acceptance for infrastructure-dependent innovations. Unlike many technologies that can be evaluated independently of supporting systems, EV adoption is associated with perceptions of the transport and energy infrastructure required for practical use [4]. The partial statistical mediation observed in the model further shows that perceived usefulness represents an important cognitive pathway linking perceived charging infrastructure availability with EV adoption intention, consistent with the underlying logic of TAM. At the same time, the moderation finding indicates that the strength of this association varies according to consumers' perceptions of electricity reliability, identifying perceived electricity reliability as an important boundary condition. These findings refine the contextual application of the TAM by indicating that technology acceptance in developing-country settings may be associated not only with the perceptions of the technology itself but also with the infrastructural and energy-system conditions that support its practical use.

5.3. Practical and Policy Implications

The findings indicate that perceived charging infrastructure availability is positively associated with EV adoption both directly and indirectly through perceived usefulness. This pattern suggests that charging infrastructure may be regarded not only as an important infrastructural condition for EV adoption intention but also as a contextual factor associated with consumers' evaluations of EVs. From a policy perspective, these findings underscore the potential value of coordinated efforts to expand reliable and accessible charging infrastructure through collaboration among government, electricity utilities and private investors. Given electricity supply constraints in Harare, greater integration of EV charging considerations into energy and transport planning may also be warranted. Renewable energy-powered charging systems could represent one potential option for strengthening energy resilience while supporting sustainable mobility. At the local level, local government authorities could consider incorporating EV charging infrastructure into transport and land-use planning and facilitating its deployment at strategically accessible locations. The statistical association between perceived charging infrastructure availability and usefulness also indicates the potential value complementing infrastructure development with targeted public awareness initiatives that communicate the economic, environmental, and practical benefits of EVs.

5.4. Limitations and Future Research Directions

This study has several limitations. First, its cross-sectional design precludes causal inference; therefore, the reported findings should be interpreted as statistical associations rather than causal effects. Longitudinal or panel studies could examine how EV-related perceptions change over time and whether adoption intentions translate into actual EV adoption. In addition, the use of self-reported measures may introduce common method and social desirability biases, despite the procedural and statistical measures implemented to mitigate these potential biases. Moreover, the use of nonprobability convenience sampling approach limits the generalisability of the findings. Although participants were recruited from diverse locations within Harare, the sample does not represent all private vehicle users in Zimbabwe. Future research should employ probability-based sampling across multiple geographical contexts to strengthen external validity.

Another limitation is that the study did not assess respondents' prior EV ownership or use, experience with public charging stations, or familiarity with EV charging infrastructure. Given the nascent state of EV adoption in Zimbabwe, respondents' perceptions of charging infrastructure may have been shaped by indirect knowledge rather than direct experience. Future studies should therefore examine the role of EV familiarity and prior exposure in shaping infrastructure-related perceptions. Finally, the model focused on perceived usefulness as the cognitive mechanism associated with EV adoption intention. Future research could extend the model by incorporating additional determinants, such as perceived risk, range anxiety, environmental concern, social influence, and facilitating conditions, to provide a more comprehensive understanding of EV adoption.

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Abbreviations

The following abbreviations are used in this manuscript:

EVI	Electric Vehicle Adoption Intention
PCIA	Perceived Charging Infrastructure Availability
PU	Perceived Usefulness
PER	Perceived Electricity Reliability
TAM	Technology Acceptance Model

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