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ATM Service Quality Dimensions and Customer Satisfaction: A SEM-Based Study in the Northern Mountainous Region of Vietnam

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Abstract

This study analyzes the impact of ATM service quality on customer satisfaction in the mountainous provinces of Northern Vietnam, where banking infrastructure is limited and ATMs still play an important role in financial access. Based on a survey of 240 customers and applying structural equation modeling (SEM), the study assesses five dimensions: Technological Integration (TI), Proximity & Coverage (PC), Security & Reliability (SR), Personalization (PE), and Eco-Friendliness (EF). The results show that the first four dimensions all have positive and significant impacts on satisfaction, of which Proximity & Coverage is the strongest factor. In contrast, Eco-Friendliness has only a weak impact. This finding is consistent with some recent studies in Thailand, Malaysia, Cambodia, and Indonesia, and adds empirical evidence in the mountainous context of Vietnam. The study contributes to the theory of electronic service quality, and at the same time suggests management implications for commercial banks in expanding their networks, improving reliability, applying technology and gradually implementing green banking.

Keywords: *ATM Service Quality; Customer Satisfaction; Structural Equation Modeling (SEM); Northern Mountainous Vietnam.*

Introduction

During the last decades, the global banking industry has witnessed unprecedented changes due to the rapid development of financial technology and the trend of digitalization. In this context, automated teller machines (ATMs) have become one of the most popular and important banking service. ATMs were first used to provide only basic utilities such as cash withdrawal and balance check, then ATMs have been rapidly upgraded to meet more diverse needs, including money transfers, bill payments, phone top-ups, and many other value-added financial services. In the changing world, many studies have been conducted and they all showed that ATM service quality has a direct impact on customer satisfaction, loyalty, and thereby on bank performance (Yoeung et al., 2023; Nigatu et al., 2023).

The provision of high-quality ATM services is particularly crucial in developing countries, where cash transactions still account for a large proportion and traditional banking infrastructure remains limited (Tadesse & Bakala, 2021). As a matter of fact, ATMs serve as a vital bridge between banks and customers, which enhances access to financial services and support the promotion of national financial strategies.

In Vietnam, the commercial banks have undergone intensive digital transformation. The government also aims to reduce the amount of cash in payments and tries to expand modern financial services to rural and mountainous areas. Although lots of digital banking services have bee deployed rapidly, ATMs still play an irreplaceable role, especially for those who are not familiar with e-banking services or who live in the regions without stable internet infrastructure. In these areas, the four state-

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owned commercial banks, BIDV, Vietcombank, Vietinbank, and Agribank, account for nearly 80 percent of the market share in mountainous areas thanks to their wide networks of ATMs.

In urban centers such as Hanoi and Ho Chi Minh city, there is high ATM density and modern infrastructure, but in the northern mountainous region, the ATM distribution is sparse and service quality is not always good. The six provinces in this region includingThai Nguyen, Phu Tho, Yen Bai, Tuyen Quang, Lang Son, and Lai Chau have rugged terrains, difficult transportation, a dispersed population, and diversity of cultures and ethnicities. Uneven socio-economic conditions make customers' needs and expectations for ATM services more specific and different from those in the urban areas. This is also a research gap, because previous domestic studies mainly surveyed urban areas or nationwide, and there have not been many in-depth studies being conducted in the mountainous areas in Vietnam (Giao, 2018).

Traditional service quality models such as SERVQUAL (Parasuraman et al., 2005), SERVPERF (Cronin & Taylor, 1992) or other variations have been widely used to assess banking services, including ATM services. Lots of studies have shown that factors such as reliability, security, responsiveness, convenience of access and physical appearance of ATMs all affect customer satisfaction (Zeithaml et al., 1996). However, the current context requires the addition of new factors that reflect the trend of sustainable development and service personalization. For example, environmental friendliness or the ability to integrate modern technology have become increasingly important criteria for ATM customers.

Based on that reality, this study proposes an analysis framework for ATM service quality with five main components including: Technological Integration (TI), Proximity & Coverage (PC), Personalization (PE), Eco-friendliness (EF) and Security & Reliability (SR). The dependent variable is Customer Satisfaction (CS). To test the model, the study makes use of Structural Equation Modeling (SEM). SEM is considered an advanced method, allowing both the assessment of reliability and scale value through CFA and the simultaneous testing of complex causal relationships between latent variables (Anderson & Gerbing, 1988). This approach ensures higher scientificity and accuracy, and provides stronger empirical evidence than traditional multiple regression techniques that have been commonly used in previous studies.

The model is analyzed with the primary data gathered from 240 observations - from four major commercial banks, located in six northern mountainous provinces. This study aims to contribute three aspects: (1) academically - expanding the theoretical framework of ATM services with two new factors, eco-friendliness and personalization, tested by SEM; (2) practically - providing data for the commercial banks to plan strategies to improve the quality of ATM services in hard-to-reach areas; and (3) policy-wise - supporting the promotion of financial inclusion and sustainable development in the northern mountainous areas of Vietnam.

Literature Review

1) Service quality and customer satisfaction

Service quality is one of the central topics in marketing and banking management. According to Parasuraman et al. (2005), service quality is reflected in the difference between customers' expectations and actual experiences. Cronin and Taylor (1992) emphasized that service quality should be measured directly from the level of perceptions, rather than the gap between expectations and reality. Meanwhile, customer satisfaction is defined by Oliver (1997) as a positive emotional state, reflecting satisfaction when the service experience meets or exceeds customers' expectations.

In the banking industry, many studies have confirmed the close relationship between service quality and satisfaction. Zeithaml et al. (1996) pointed out that service quality not only affects satisfaction but also affects repurchase behavior, such as loyalty and positive words of mouth. Therefore, studying the relationships between ATM service quality and customer satisfaction has both theoretical and practical significance.

2) Previous studies on ATM services

Many international studies have shown the pivotal role of ATM service quality in customer satisfaction. Yoeung et al. (2023) in Cambodia showed that factors such as transaction speed, security, and convenience have strong impacts on customer satisfaction. Tadesse and Bakala (2021) in Ethiopia emphasized that availability and reliability are among the most important factors. Nigatu et al. (2023) added that security and stability of the ATM system are the important determinants of customer trust.

In Southern Asia, Aslam et al. (2019) used SEM to analyze data in Pakistan and found that ATM service quality significantly impacted not only satisfaction but also loyalty. In India, Gupta and Bansal (2012) found that convenience, speed, and availability of ATMs are the most important factors for customers to continue using the ATM service. In Africa, Komal and Singh (2021) in Nigeria demonstrated that coverage and convenience are the decisive factors in customers' choices of banks' ATM services. These mentioend results show that, regardless of the geographical issues, factors such as security, reliability, and convenience always play a central role in customer satisfaction on ATM services.

Recent studies have begun to extend the approach to new dimensions of ATM service quality. Rysin et al. (2023) discussed the application of digital technologies to personalize ATM and banking experiences, leading to higher customer satisfaction and loyalty. Suryanto (2025) also showed that digital technologies such as mobile banking and big data analytics help to personalize banking services, while also setting the way for ATMs to continue to play an important role in the digital banking ecosystem.

In Vietnam, although there have been many researches on ATM services, these works conduted by university sstudents focused mainly on assessing the levels of customers on the ATM services. The relationships between dimensions of ATM service quality and customer satisfaction have not been well ditermined. Giao (2018) with the SERVPERF model at Vietcombank Vinh Long showed that "Assurance" and "Tangibles" are the two factors that most strongly influence satisfaction. Some other studies on digital banking services focus on mobile banking or internet banking, but there have not been many specific surveys on ATMs in the mountainous context - where infrastructure, geography and population conditions are specific. This gap shows that more empirical researches are needed to clarify the factors affecting ATM customer satisfaction in the mountainous region of Northern Vietnam.

3) Factors in the research model

Based on the synthesis from theory and practice, five main factors are selected for the research framework:

- *Technological Integration (TI):* The level of technology integration including processing speed, connectivity, and system modernization. Phan & Thuy (2023) demonstrated that the application of new technology significantly improves the quality of banking services.

- *Proximity & Coverage (PC):* Convenience in location and coverage of ATM network, which makes it easy for customers to access (Tadesse & Bakala, 2021).

- *Personalization (PE):* The degree to which the experience is personalized, such as language selection, interface, and tailored services. Recent studies show that customers increasingly expect personalized experiences (Suryanto, 2025; Rysin et al., 2023).

- Eco-friendliness (EF): Environmental friendliness, in line with the sustainable development trend of the modern banking industry (Aslam et al., 2019).

- Security & Reliability (SR): The level of safety and reliability of the service, directly related to information security and system stability (Nigatu et al., 2023).

The dependent variable is Customer Satisfaction (CS), which reflects the overall satisfaction of customers after experiencing ATM services (Oliver, 1997).

4) Application of SEM and Hypothesis Formation

Structural Equation Modeling (SEM) is considered an advanced analytical method that allows simultaneous testing of measurement models (through CFA) and structural models (Anderson & Gerbing, 1988). Unlike traditional linear regression, SEM can solve many complex causal relationships between latent variables. Many recent studies have applied SEM in banking services, typically Aslam et al. (2019), thereby improving the reliability of research results.

3. Proposed Research Model & Hypotheses

Based on the theoretical foundation of service quality and customer satisfaction (Parasuraman et al., 2005; Oliver, 1997) and previous empirical studies (Aslam et al., 2019; Nigatu et al., 2023; Yoeung et al., 2023), this study builds a conceptual framework to test the impact of five independent factors on customer satisfaction using ATM services in the mountainous region of Northern Vietnam.

The selected factors reflect both traditional elements of ATM service quality such as safety and reliability and emerging trends such as technology integration and environmental friendliness. The model is designed to be tested using Structural Equation Modeling (SEM), which allows for simultaneous assessment of scale reliability and causal relationships between latent variables (Anderson & Gerbing, 1988).

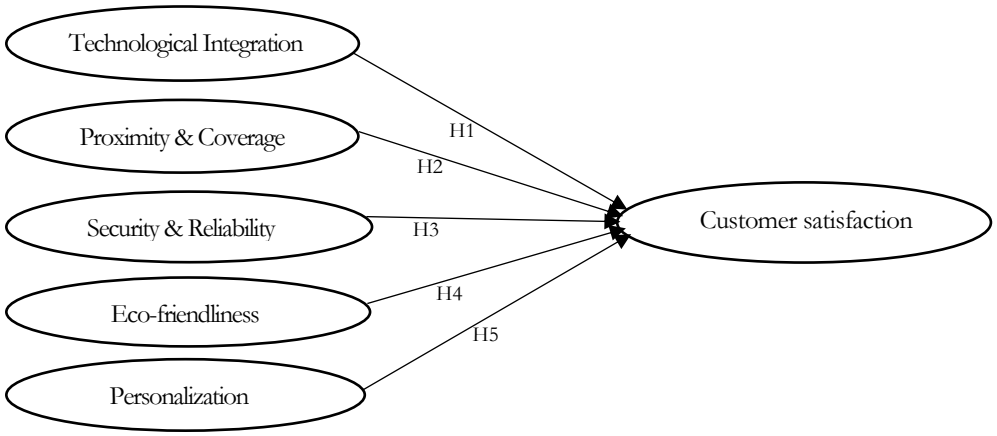

Figure 1. Proposed Research Model

Based on the research model, five hypotheses are built as follows:

- H1: Technological Integration (TI) has a positive impact on Customer Satisfaction (CS) - Modern technology helps increase processing speed, stability and enhance customer experience (Phan & Thuy, 2023).

- H2: Proximity & Coverage (PC) has a positive impact on Customer Satisfaction (CS) - Convenient ATM network, reasonable distribution helps customers easily access, thereby improving satisfaction (Tadesse & Bakala, 2021).

- H3: Security & Reliability (SR) has a positive impact on Customer Satisfaction (CS) - Safety and reliability in transactions are fundamental factors to build trust and satisfaction (Nigatu et al., 2023).

- H4: Eco-friendliness (EF) has a positive impact on Customer Satisfaction (CS) - Concerns about sustainable development make customers appreciate environmentally friendly services, including energy-saving ATMs or those that minimize ecological impacts (Aslam et al., 2019).

- H5: Personalization (PE) has a positive impact on Customer Satisfaction (CS) - Personalization (language, interface, appropriate services) is increasingly expected by customers and contributes to creating a differentiated experience (Suryanto, 2025; Rysin et al., 2023).

In summary, the proposed research model provides a theoretical framework to test the factors affecting ATM customer satisfaction in a specific context - the mountainous region of Northern Vietnam. The application of SEM in testing helps to ensure scientificity, reliability and creates new contributions to the field of banking service quality research.

Research Methodology

Research Design

This study makes use of a quantitative design with a structured questionnaire survey method to analyze the proposed research model of the impact of ATM service quality on customer satisfaction. Structural Equation Modeling (SEM) method was used because of its ability to not only analyze complex relationships between latent variables but also simultaneously evaluate both the measurement model and the structural model (Hair et al., 2021).

Sample and Data Collection

The respondents of the study were customers who have used ATM services for at least 6 months provided by the four largest commercial banks in the mountainous region of Northern Vietnam: BIDV, Vietcombank, Vietinbank and Agribank. The sample was stratified by bank, with 60 respondents from each bank, thus, there were 240 customers serving as the respondents.

The survey was conducted in six mountainous provinces: Thai Nguyen, Phu Tho, Yen Bai, Tuyen Quang, Lang Son and Lai Chau to ensure representativeness of the socio-economic characteristics and banking infrastructure of the mountainous region. A convenient sampling method was used to ensure the equal distribution between provinces and banks.

The primary data was collected in the second quarter of 2025 via two ways: distributing questionnaires directly at ATMs and sending electronic surveys to the group of customers who regularly make transactions. The participants were guaranteed anonymity and the right to participate voluntarily.

Measurement Instrument

To build the proposed research model, the scales were inherited from previous studies and adjusted to suit the context in Vietnam. Table 1 summarizes the research factors, the number of observed variables, a general description of the measurement content as well as the reference sources used to build the scale.

Table 1. Constructs, Number of Items, and Sources of Measurement

Factor/Code	Number of items	Description	Sources of Measurement
Technological Integration (TI)	4	Measure the level of technology application in ATMs (processing speed, user-friendly interface, digital service integration)	Alalwan et al. (2022); Phan & Thuy (2023)
Proximity & Coverage (PC)	4	Assess the convenience of distribution, density and accessibility of ATM network.	Tadesse & Bakala (2021); Nguyen et al. (2020)
Security & Reliability (SR)	4	Measure the level of safety, reliability and stability in transactions.	Nigatu et al. (2023); Zhou et al. (2019)
Eco-friendliness (EF)	4	Reflects commitment to environmental protection in ATM operations (energy saving, reducing ecological impact)	Aslam et al. (2019); Nguyen et al. (2023)
Personalization (PE)	4	Personalize services according to customer needs (language, interface, appropriate services)	Ahn & Lee (2022); Rysin et al. (2023); Suryanto (2025)
Customer Satisfaction (CS)	3	Measure overall customer satisfaction with ATM services.	Oliver (2014); Zeithaml et al. (1996)

Source: Compiled by the authors based on prior studies

All factors were measured using multiple observation variables with a 5-level Likert scale (1 = Completely disagree; 5 = Completely agree). These scales have been verified in many previous studies, thereby ensuring content validity and reliability when applied in this study.

Data Analysis Methods

The survey data was processed using SPSS 20 and AMOS 24 software, following a multi-step analysis process commonly recommended in SEM research (Hair et al., 2019). First, the data were screened for missing values, outliers, and normal distribution was assessed, which helps to ensure the reliability of subsequent statistical analyses.

The reliability and validity of the scale were assessed using Cronbach's alpha and Composite Reliability (CR), with Cronbach's alpha ≥ 0.7 and CR ≥ 0.7 acceptance thresholds (Hair et al., 2019). Convergent validity was tested using Average Variance Extracted (AVE), with AVE ≥ 0.5 criteria (Fornell & Larcker, 1981). Discriminant validity was assessed using the Fornell–Larcker criterion and the Heterotrait–Monotrait ratio, with HTMT threshold < 0.85 (Henseler et al., 2015).

In order to ensure the validity of the measurement structure, the study conducted exploratory factor analysis (EFA) to test the latent structure, then performed confirmatory factor analysis (CFA) to confirm the measurement model. The suitability of the model was assessed based on various indices, including

Chi-square/df, Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), and Root Mean Square Error of Approximation (RMSEA). Based of recommendations, the model meets the standard when CFI and TLI ≥ 0.9; RMSEA ≤ 0.08; and Chi-square/df ≤ 3 (Hu & Bentler, 1999).

Finally, structural equation modeling (SEM) was used to test the research hypotheses. Path coefficients and statistical significance levels (p-values) were analyzed to assess the impact of independent variables (TI, PC, PE, EF, SR) on the dependent variable (CS). The results of SEM allow for both testing direct relationships and assessing the overall fit of the model, thereby providing empirical evidence for the proposed hypotheses.

Ethical Considerations

The respondents were clearly informed about the research objectives. All data would be used for academic purposes only. Personal information was kept completely confidential. The study complied with ethical principles in social science research.

Results

Descriptive Statistics of Respondents

Table 2. Respondents' Demographic Profile (N = 240)

Variable	Frequency (person)	Percent (%)
Gender		
Male	128	53.3
Female	112	46.
Age		
Up to 30 years	114	47.5
From 31 to 40 years	84	35.0
41 years and above	42	17.5
Marital Status		
Single	74	30.8
Married	166	69.2
Monthly Income		
Less than 10 million VND	64	26.7
From 10 to 20 million VND	141	58.8
More than 20 million VND	35	14.6
Job Position		
State servant	40	16.7
Company employee	111	46.3
Student	34	14.2
Other	55	22.9
Education Attainment		
Below university level	150	62.5
Bachelor degree	75	31.3
Master's degree and above	15	6.3
Length of ATM Service Use		
Less than 5 years	30	12.5
From 5 to 10 years	99	41.3
More than 10 years	111	46.3

Authors' computation (2025)

Table 2 presents descriptive statistics on the demographic characteristics of the 240 respondents who participated in the survey. The results show that the survey sample has a fairly balanced distribution in terms of gender, age, marital status, income, occupation, education level and experience using ATM services.

In terms of gender, the proportion of men accounts for 53.3% (128 people), slightly higher than that of women (46.7%, 112 people). This reflects the relatively balanced participation of both genders in the study, thereby ensuring objectivity in assessing the quality of ATM services.

In terms of age, the group under 30 years old accounts for the highest proportion (47.5%), followed by the group from 31 to 45 years old (35.0%), while the group from 41 years old and above accounts for only 17.5%. This structure shows that the majority of ATM users are young customers, who are closely attached to modern banking services.

With regard to marital status, the majority of respondents are married (69.2%), while the rate of singles is 30.8%. This factor may suggest that the group of customers with families often use ATMs for spending needs and managing household finances.

Regarding to monthly income, the majority of respondents have an income of 10-20 million VND/month (58.8%). The group with income under 10 million accounts for 26.7% and over 20 million accounts for 14.6%. This structure reflects the focus of the sample on the middle-income group, which is the main customer group of ATM services.

In terms of job position, company employees accounted for the highest proportion (46.3%), followed by other occupations (22.9%), government officials (16.7%) and students (14.2%). This shows that the majority of regular ATM users are employees in the business sector.

With regard to education level, up to 62.5% of survey participants had a degree below university level, while the group with a bachelor's degree accounted for 31.3% and those with a postgraduate degree accounted for only 6.3%. This result reflects that ATM services are not only popular with the highly educated group but are also widely used among the general and secondary education levels.

In terms of time of ATM service use, nearly half of the respondents (46.3%) have used ATMs for over 10 years, indicating a long-term commitment and experience with the service. The group from 5 to 10 years accounts for 41.3%, while under 5 years accounts for only 12.5%. This confirms that ATM services have become a familiar part of people's financial lives.

Descriptive Analysis of Constructs

Table 3. Descriptive Statistics for ATM Service Quality Constructs and Customer Satisfaction

Construct	Mean (M)	Std. Deviation (SD)
Technological Integration (TI)	3.40	0.69
Proximity & Coverage (PC)	3.59	0.75
Security & Reliability (SR)	3.54	0.82
Eco-friendliness (EF)	3.63	0.73
Personalization (PE)	3.35	0.77
Customer Satisfaction	3.51	0.58

Authors' computation (2025)

Table 3 presents the descriptive statistics for the constructs measuring ATM service quality and customer satisfaction. The mean values ranged from 3.35 to 3.63 on a 5-point Likert scale, indicating that customers generally tended to rate the ATM service quality aspects at a fairly average level.

First, the Eco-friendliness (EF) factor achieved the highest mean value (M = 3.63; SD = 0.73), reflecting that customers positively evaluated the environmental friendliness of ATM services, which may be related to saving on receipt paper or applying green technology.

Second, Proximity & Coverage (PC) (M = 3.59; SD = 0.75) and Security & Reliability (SR) (M = 3.54; SD = 0.82) were also rated quite highly. This shows that customers appreciate the convenience of ATM location as well as the level of safety and reliability when making transactions.

Third, Customer Satisfaction reached an average of 3.51 (SD = 0.58), which is relatively positive but not really outstanding, implying that the current ATM experience only meets a fairly satisfactory level of satisfaction.

Fourth, the two factors with the lowest average scores are Technological Integration (TI) (M = 3.40; SD = 0.69) and Personalization (PE) (M = 3.35; SD = 0.77). This shows that customers have not really felt clearly the integration of modern technology or personalization in ATM services.

Overall, the dispersion level (SD) of the variables ranges from 0.58 to 0.82, indicating a certain difference in customer perception, but not too large. This result suggests that banks should focus on improving technological aspects and service personalization, while maintaining and enhancing currently

highly valued factors such as environmental friendliness, coverage and safety, to further enhance customer satisfaction.

Reliability Analysis

Table 4. Cronbach's Alpha for Measurement Constructs

Factors	No. of Items	Cronbach's Alpha (α)
Technological Integration (TI)	4	0.834
Proximity & Coverage (PC)	4	0.844
Security & Reliability (SR)	4	0.869
Eco-friendliness (EF)	4	0.845
Personalization (PE)	4	0.854
Customer Satisfaction	3	0.982

Authors' computation (2025)

Table 4 presents the results of reliability testing of the scales via Cronbach's Alpha coefficients. All factors have Alpha coefficients which are greater than 0.8, exceeding the usual acceptance threshold (≥ 0.7), demonstrating that the observed variables in each scale are closely linked and highly reliable.

- Technological Integration (TI) has a coefficient of α = 0.834, indicating that this scale has good reliability.

- Proximity & Coverage (PC) and Eco-friendliness (EF) have coefficients of α of 0.844 and 0.845, respectively, both demonstrating stable internal consistency.

- Security & Reliability (SR) has α = 0.869, a high level, reflecting a good connection between observed variables on ATM service safety and reliability.

- Personalization (PE) has α = 0.854, which also ensures high reliability in measuring the level of personalization.

- Customer Satisfaction has a very high α coefficient (0.982), showing that the observed variables in this scale have almost absolute homogeneity.

- In conclusion, the results of Cronbach's Alpha analysis confirm that all scales used in the study are reliable to continue to conduct exploratory and confirmatory analyses (EFA, CFA) as well as the SEM structural model.

Exploratory Factor Analysis (EFA)

Table 5. Results of Exploratory Factor Analysis (EFA)

Indicator	Value
Kaiser-Meyer-Olkin - KMO	.891
Measure of Sampling	3622.59 (df = 253, p < 0.001
Number of Components (Eigenvalue > 1)	6
Cumulative Variance Explained	73.53

Authors' computation (2025)

Table 5 presents the main indicators of the exploratory factor analysis (EFA). First, the Kaiser-Meyer-Olkin (KMO) coefficient reached 0.891, far exceeding the minimum threshold of 0.5 and falling within the "very good" range (0.8–0.9). This proves that the survey data is suitable for factor analysis.

The result of Bartlett's Test of Sphericity gave a Chi-square value of 3622.59 with df = 253 and a significance level of p < 0.001. This shows that the correlation matrix between the observed variables is significantly different from the identity matrix, meaning that the variables are closely related and suitable for factor analysis.

The analysis also shows that there are 6 factors extracted with Eigenvalue > 1, consistent with the initial research hypothesis. These six factors represent the main latent constructs in the ATM service quality and customer satisfaction model.

Finally, the total explained variance reached 73.53%, exceeding the 50% threshold commonly accepted in social research. This confirms that the six extracted factors are capable of explaining most of the variation in the data, ensuring the validity in measuring the research concepts.

The extracted factors align well with the conceptual framework, representing the following constructs: Factor 1: Security & Reliability (SR); Factor 2: Personalization (PE); Factor 3: Proximity & Coverage (PC); Factor 4: Eco-friendliness (EF); Factor 5: Technological Integration (TI); and Factor 6: Customer Satisfaction (CS).

In conclusion, the EFA results show that the scale used in the study is appropriate, valuable and reliable to continue conducting the confirmatory analysis (CFA) and structural equation modeling (SEM).

Confirmatory Factor Analysis (CFA)

The results of CFA analysis showed that the measurement model had a very good fit with the survey data. All fit indices exceeded the recommended thresholds of Hu & Bentler (1999), specifically: CMIN/DF = 1.034 (< 3), CFI = 0.998 (> 0.90), TLI = 0.998 (> 0.90), IFI = 0.998 (> 0.90), RMSEA = 0.012 (< 0.08) and PCLOSE = 1.000 (> 0.05). The standardized loading factors of the observed variables were all greater than 0.6 and statistically significant, demonstrating that the scale achieved convergent validity. These results confirm that the measurement model has high suitability, which is the basis for continuing to test the reliability (Cronbach's Alpha, CR, AVE) and discriminant validity (HTMT) of the scales.

Table 6. Summary of CFA Results

Construct	Cronbach's α	CR	AVE	Conclusion
TI1234	0.834	.835	.558	Reliable, valid
EF1234	0.844	.846	.579	Reliable, valid
SR1234	0.869	.872	.630	Reliable, valid
PE1234	0.845	.856	.599	Reliable, valid
PC1234	0.854	.849	.585	Reliable, valid
CS123	0.982	.982	.947	Reliable, valid

Authors' computation (2025)

The CFA results in Table 6 show that all scales have achieved reliability and convergent validity. First, the Cronbach's Alpha coefficients of the factors range from 0.834 to 0.982, higher than the threshold of 0.7 (Nunnally & Bernstein, 1994), demonstrating that the scales have good internal reliability. In particular, the "Customer Satisfaction" scale (CS123) has Cronbach's Alpha = 0.982, demonstrating a very high level of consistency between observed variables.

Second, the Composite Reliability (CR) indexes of the factors are all greater than 0.8 (from 0.835 to 0.982), exceeding the minimum threshold of 0.7 proposed by Fornell & Larcker (1981). This confirms that the scales have good composite reliability and ensure stability when applied to empirical research.

Third, the Average Variance Extracted (AVE) values are all greater than 0.5 (ranging from 0.558 to 0.947), indicating that the observed variables explain more than 50% of the variance of the latent concept. This is important evidence confirming the convergent validity of the scale. Notably, the CS123 scale has AVE = 0.947, demonstrating a very high level of convergence.

Table 7. HTMT Analysis for Constructs

Construct	HTMT					
	TI1234	EF1234	SR1234	PE1234	PC1234	CS123
TI1234	—	.439	.266	.113	.168	.437
EF1234		—	.421	.330	.208	.473
SR1234			—	.508	.362	.598
PE1234				—	.409	.563
PC1234					—	.536
CS123						—

Authors' computation (2025)

Table 7 presents the results of the analysis of the multitrait–multimethod correlation (HTMT) ratio between pairs of factors in the model. The obtained HTMT values ranged from 0.113 to 0.598, all lower than the threshold of 0.85 proposed by Henseler et al. (2015), and also lower than the strict threshold of 0.90 commonly applied in social studies. This shows that the scales in the study achieved good

discriminant validity, that is, each factor reflects a separate latent concept and does not overlap in measurement content. In detail, the factor pairs with the lowest correlation are between Technological Integration (TI1234) and Personalization (PE1234) (HTMT = 0.113), while the pair with the highest correlation is Security & Reliability (SR1234) and Customer Satisfaction (CS123) (HTMT = 0.598). Despite the differences in the degree of association, all these values are within acceptable limits, thereby strengthening the evidence that the scales do not violate the assumption of conceptual distinction.

Thus, combined with the previous CFA results (Cronbach's Alpha, CR, AVE all met the standards), it can be affirmed that the scales in the study have achieved both convergent and discriminant validity. This is a solid foundation for conducting the structural equation modeling (SEM) analysis steps in the next section.

Structural Model and Hypotheses Testing

The structural model was estimated using Structural Equation Modeling (SEM) in AMOS to test the hypothesized relationships between the five dimensions of ATM service quality and customer satisfaction.

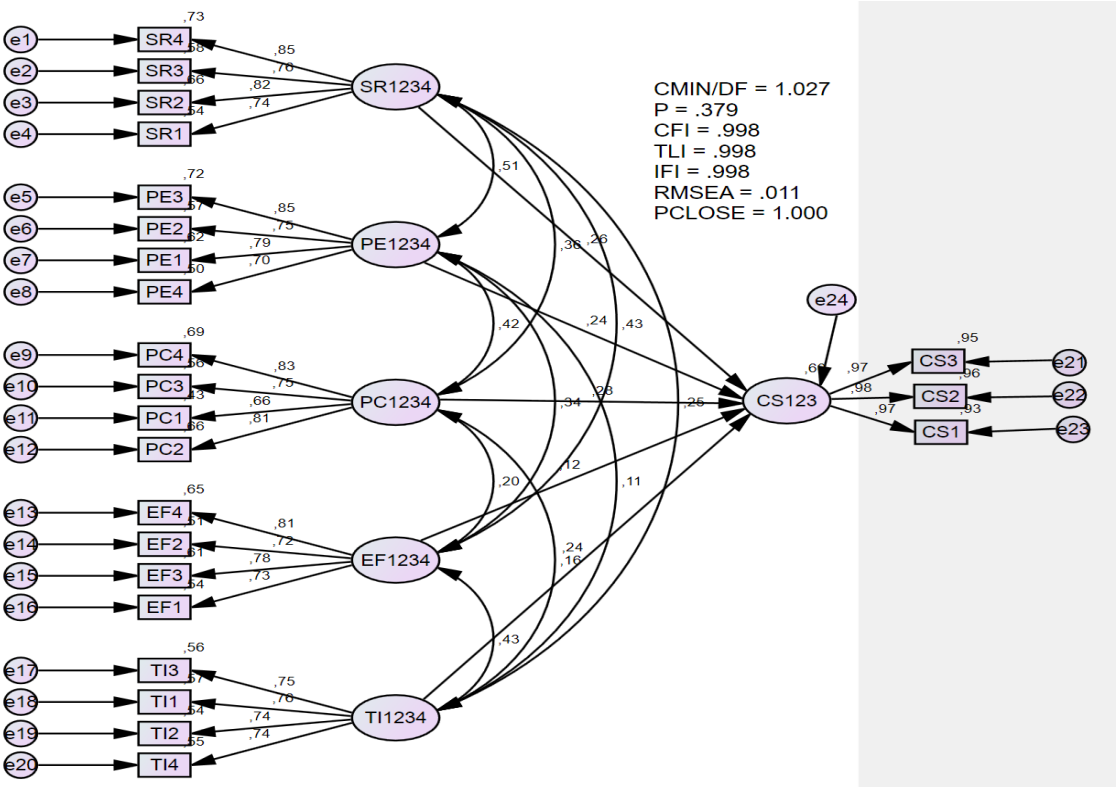

Figure 2. Structural Equation Model for ATM Service Quality and Customer Satisfaction

Figure 2 shows Structural Equation Modeling (SEM) to test the impact of ATM service quality on customer satisfaction. The model fit evaluation indexes are all very good: CMIN/DF = 1.027 (< 3), CFI = 0.998, TLI = 0.998, IFI = 0.998, RMSEA = 0.011 (< 0.05), PCLOSE = 1.000, showing that the SEM model fits the experimental data excellently.

Regarding the standardized loading factors of the observed variables, all are above 0.70, demonstrating that the measured variables reflect the latent factors well. In particular, the Customer Satisfaction (CS) factor has a loading factor from 0.93 to 0.97, reflecting a very strong convergence level.

Regarding the causal relationship, the SEM results indicate that ATM service quality factors (Security & Reliability, Personalization, Proximity & Coverage, Eco-friendliness, Technological Integration) all have a positive impact on Customer Satisfaction. The standardized regression coefficients range from 0.11 to 0.43, in which the strongest impact on satisfaction is Security & Reliability (SR) and Personalization (PE).

In conclusion, The SEM shows that the scales used in the study have high validity and reliability, and proves that ATM service quality is an important determinant of customer satisfaction. This strengthens the theoretical basis and provides empirical evidence for banks to focus on improving service quality to enhance customer experience and satisfaction.

Table 8. Standardized Regression Weights and Hypothesis Testing

Hypot-hesis	Path	Estimate (β)	S.E.	C.R.	p-value	Result
H1	Technological Integration (TI) → Customer Satisfaction (CS)	0.242	0.43	4.129	***	Supported
H2	Proximity & Coverage (PC) → Customer Satisfaction (CS)	0.285	0.47	3.741	***	Supported
H3	Security & Reliability (SR) → Customer Satisfaction (CS)	0.259	0.46	5.028	***	Supported
H4	Eco-friendliness (EF) → Customer Satisfaction (CS)	0.120	0.48	1.962	0.05	Weakly supported
H5	Personalization (PE) → Customer Satisfaction (CS)	0.235	0.54	4.173	***	Supported

Authors' computation (2025)

*Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$. The model explains 60% of the variance in Customer Satisfaction ($R^2 = 0.6$).*

The results of the structural model testing show that all five hypotheses H1–H5 have a positive impact on customer satisfaction, although the impact levels are different. First, Proximity & Coverage (PC) has the highest impact coefficient ($\beta = 0.285$; $p < 0.001$), confirming that the reasonable distribution and convenient accessibility of the ATM network are key factors in improving customer satisfaction. Next, Security & Reliability (SR) also has a significant impact ($\beta = 0.259$; $p < 0.001$), indicating that safety and stability in transactions are the foundation for building trust and satisfaction. Other factors such as Technological Integration (TI) ($\beta = 0.242$; $p < 0.001$) and Personalization (PE) ($\beta = 0.235$; $p < 0.001$) all have positive and statistically significant impacts, emphasizing the role of modern technology application as well as service personalization in enhancing customer experience. This is consistent with recent research trends, where banks invest heavily in technology and experience optimization to maintain customer loyalty.

Notably, Eco-friendliness (EF) has the lowest impact and is only "weakly supported" ($\beta = 0.120$; $p = 0.05$). This result suggests that environmental friendliness, although increasingly concerned, is not yet a top priority for customers in assessing satisfaction with ATM services.

Overall, the research model explains 60% of the variance in customer satisfaction ($R^2 = 0.600$), indicating a fairly high level of explanatory power. Thus, it can be concluded that the factors of convenience, safety, technology and personalization of ATM services are the key factors affecting customer satisfaction, while the environmental friendliness factor only plays a supporting role.

Discussion

The research results confirmed the important role of ATM service quality on customer satisfaction in the context of Vietnam. In particular, Proximity & Coverage (PC) has the strongest impact ($\beta = 0.285$), reflecting that the convenience and coverage of the ATM network are still key factors that help customers save time and transaction costs. This finding is similar to the study in Thailand, where "service convenience" was identified as the leading factor affecting customer satisfaction and loyalty in the retail banking industry (Shibasaki & Rahothan, 2025).

The factors Security & Reliability (SR) ($\beta = 0.259$), Technological Integration (TI) ($\beta = 0.242$) and Personalization (PE) ($\beta = 0.235$) all have significant impacts, consistent with studies in the region. In Malaysia, Lim, Yeo, Tey, and Tan (2023) found that perceived reliability, security, and perceived usefulness were determinants of satisfaction with e-banking services. Similarly, in Vietnam, Nguyen et al. (2022) found that e-service quality had a significant impact on the intention to use video teller machines (VTM), emphasizing the importance of integrating modern technology in enhancing customer

experience. These findings suggest that banks need to focus on transaction security, new technology adoption, and personalization to maintain and enhance satisfaction.

In contrast, Eco-friendliness (EF) had only a weak impact ($\beta = 0.120$, $p = 0.05$). This result implies that although customers are aware of the "environmentally friendly" factor, they do not consider it a major determinant of satisfaction. This finding is similar to research in Cambodia (Yoeung, Hill, & Ung, 2023) and Indonesia (Putra & Dewi, 2025), in which convenience, ease of use and reliability are the factors that have the strongest influence on satisfaction, while the "green" factor has not played a decisive role.

Overall, the research results in Vietnam are consistent with the general trend in the Southeast Asian region: convenience/coverage is always the most prominent factor, followed by reliability - safety, technology integration and personalization, while environmental friendliness only plays a supporting role. This suggests that commercial banks need to prioritize network expansion, ensure safety, invest in modern technology and gradually develop "green banking" solutions to improve customer experience in a comprehensive and sustainable way.

Conclusion and Implications

Conclusion

This study was conducted using SEM to assess the impact of ATM service quality factors on customer satisfaction in the northern mountainous provinces of Vietnam. The results showed that four main factors – Proximity & Coverage, Security & Reliability, Technological Integration, and Personalization – all had positive and statistically significant impacts on satisfaction. Of which, Proximity & Coverage was the strongest factor, confirming the important role of convenience and ATM network coverage in areas with limited financial and banking infrastructure. In contrast, Eco-friendliness had only a weak impact, indicating that customers did not consider this a direct deciding factor.

This result is consistent with recent studies in the Southeast Asian region, such as in Thailand (Shibasaki & Rahothan, 2025), Malaysia (Lim et al., 2023), Cambodia (Yoeung et al., 2023), and Indonesia (Putra & Dewi, 2025). At the same time, the study also adds empirical evidence in the specific context of the northern mountainous provinces of Vietnam, where ATM services still play a key role in helping people access retail banking services.

Theoretical Implications

Academically, the study contributes to strengthening and expanding the theoretical framework on e-service quality (Parasuraman et al., 2005) in the specific context of a developing region with limited infrastructure. The confirmation of the role of convenience, safety - reliability, technology integration and personalization shows that the measurement model is generalizable, and opens up a new research direction on "green" banking services (eco-friendly banking), which are not highly appreciated by customers in mountainous areas but can become a long-term competitive advantage.

Managerial Implications

In terms of practice, the research results suggest some managerial implications for the commercial banks operating in the mountainous areas of Northern Vietnam:

- Expanding and optimizing the ATM network: Due to the large area and dispersed population, banks need to arrange ATMs at concentrated residential areas, near markets, industrial parks or schools to improve convenience.

- Strengthening security and reliability: Mountainous areas often have limited infrastructure monitoring, so it is necessary to invest heavily in security systems, stable transmission lines and quick incident support services.

- Promote technology integration: Applying cardless withdrawals, biometric authentication or linking e-wallets will help overcome the technology gap and improve customer experience.

- Develop service personalization: Integrating language selection (especially popular ethnic languages), storing frequently used transactions will create friendliness and increase local customer engagement.

- Encourage “green banking” initiatives: Although the impact is not yet large, deploying energy-saving ATMs, encouraging transactions without printing invoices... will help banks improve their image and social responsibility.

Limitations and Future Research

This study still has certain limitations. First, the data was collected in the mountainous areas of Northern Vietnam, so it does not fully reflect the entire Vietnamese ATM field. Second, the model only considers five factors, while customer satisfaction can be affected by many other factors. Further studies can expand the scope of the survey, add more intermediate or moderating variables, as well as compare the results between different groups of banks or regions.

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Ethical Considerations

This study strictly adheres to ethical standards in social science research. The respondents were fully informed about the objectives, procedures and benefits before the survey. They participated on a voluntary basis. The data were anonymized, confidential and used for academic purposes only. The study ensured minimal risk, respect for the dignity, privacy and autonomy of all participants.

Conflict of Interest

The author declares that there are no conflicts of interest in this study.

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Appendice

Appendix A. Exploratory Factor Analysis (EFA)

KMO, Bartlett's Test, Total Variance Explained, Rotated Component Matrix

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,891
Bartlett's Test of Sphericity	Approx. Chi-Square	3622,549
	df	253
	Sig.	,000

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7,811	33,959	33,959	7,811	33,959	33,959	3,060	13,303	13,303
2	2,850	12,391	46,350	2,850	12,391	46,350	2,969	12,910	26,213
3	2,082	9,053	55,403	2,082	9,053	55,403	2,932	12,748	38,961
4	1,629	7,081	62,484	1,629	7,081	62,484	2,820	12,259	51,220
5	1,535	6,674	69,158	1,535	6,674	69,158	2,813	12,231	63,451
6	1,005	4,368	73,527	1,005	4,368	73,527	2,317	10,075	73,527
7	,611	2,658	76,185						
8	,587	2,551	78,736						
9	,505	2,196	80,932						
10	,458	1,993	82,925						
11	,445	1,935	84,860						
12	,438	1,903	86,763						
13	,409	1,777	88,540						
14	,396	1,721	90,262						
15	,385	1,675	91,937						

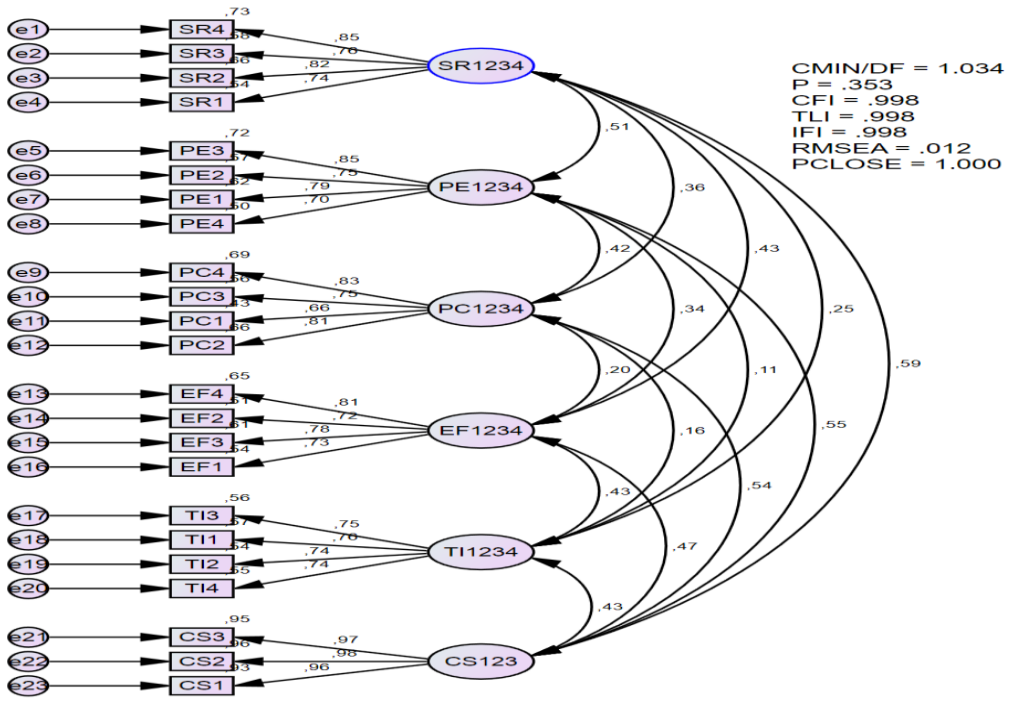
Rotated Component Matrix[a]

	Component					
	1	2	3	4	5	6
SR4	,821					
SR3	,787					
SR2	,786					
SR1	,784					
PE3		,816				
PE2		,796				
PE1		,795				
PE4		,757				
PC4			,813			
PC3			,809			
PC1			,785			
PC2			,784			
EF4				,820		
EF2				,819		
EF3				,764		
EF1				,747		
TI3					,818	
TI1					,797	
TI2					,792	
TI4					,769	
CS3						,811
CS2						,808
CS1						,776

Extraction Method: Principal Component Analysis.

a. Rotation converged in 6 iterations.

Appendix B. Confirmatory Factor Analysis (CFA)



Model Fit Summary

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	84	222,212	215	,353	1,034
Saturated model	299	,000	0		
Independence model	46	3756,136	253	,000	14,846

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	,941	,930	,998	,998	,998
Saturated model	1,000		1,000		1,000
Independence model	,000	,000	,000	,000	,000

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	,850	,800	,848
Saturated model	,000	,000	,000
Independence model	1,000	,000	,000

NCP

Model	NCP	LO 90	HI 90
Default model	7,212	,000	46,714
Saturated model	,000	,000	,000
Independence model	3503,136	3308,528	3705,058

FMIN

Model	FMIN	F0	LO 90	HI 90
Default model	,930	,030	,000	,195
Saturated model	,000	,000	,000	,000
Independence model	15,716	14,657	13,843	15,502

RMSEA

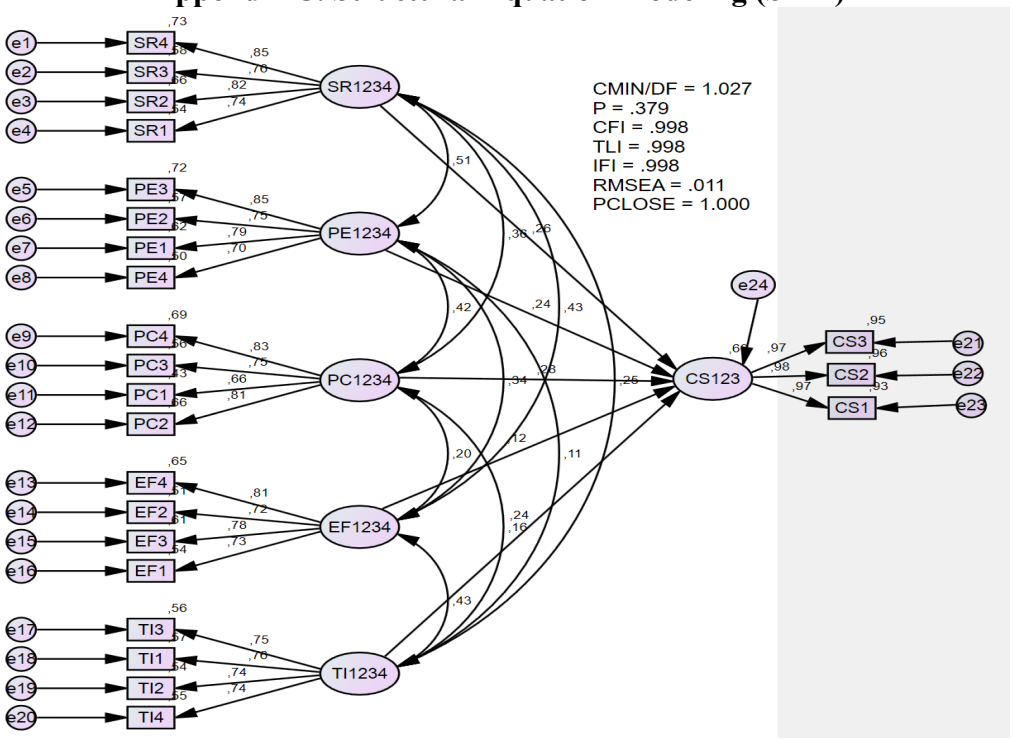
Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	,012	,000	,030	1,000
Independence model	,241	,234	,248	,000

Standardized Regression Weights: (Group number 1 - Default model)

			Estimate
SEC4	<---	SEC1234	,853
SEC3	<---	SEC1234	,764
SEC2	<---	SEC1234	,815
SEC1	<---	SEC1234	,738
REL3	<---	REL1234	,847
REL2	<---	REL1234	,754
REL1	<---	REL1234	,785
REL4	<---	REL1234	,704
CON4	<---	CON1234	,829
CON3	<---	CON1234	,751
CON1	<---	CON1234	,659
CON2	<---	CON1234	,810
RES4	<---	RES1234	,806
RES2	<---	RES1234	,716
RES3	<---	RES1234	,783
RES1	<---	RES1234	,734
TAN3	<---	TAN1234	,748
TAN1	<---	TAN1234	,757
TAN2	<---	TAN1234	,737
TAN4	<---	TAN1234	,745
CS3	<---	CS123	,974
CS2	<---	CS123	,981
CS1	<---	CS123	,964

Intercepts: (Group number 1 - Default model)

Appendix C. Structural Equation Modeling (SEM)



Model Fit Summary

CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	82	222,811	217	,379	1,027
Saturated model	299	,000	0		
Independence model	46	3756,136	253	,000	14,846

Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	,941	,931	,998	,998	,998
Saturated model	1,000		1,000		1,000
Independence model	,000	,000	,000	,000	,000

Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	,858	,807	,856
Saturated model	,000	,000	,000
Independence model	1,000	,000	,000

NCP

Model	NCP	LO 90	HI 90
Default model	5,811	,000	45,258
Saturated model	,000	,000	,000
Independence model	3503,136	3308,528	3705,058

FMIN

Model	FMIN	F0	LO 90	HI 90
Default model	,932	,024	,000	,189
Saturated model	,000	,000	,000	,000
Independence model	15,716	14,657	13,843	15,502

RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	,011	,000	,030	1,000
Independence model	,241	,234	,248	,000

AIC

Standardized Regression Weights: (Group

			Estimate
CS123	<---	SR1234	,259
CS123	<---	PE1234	,235
CS123	<---	PC1234	,285
CS123	<---	EF1234	,120
CS123	<---	TI1234	,242
SR4	<---	SR1234	,853
SR3	<---	SR1234	,764
SR2	<---	SR1234	,815
SR1	<---	SR1234	,738
PE3	<---	PE1234	,847
PE2	<---	PE1234	,754

Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
CS123	<---	SR1234	,179	,043	4,129	***	par_26
CS123	<---	PE1234	,175	,047	3,741	***	par_27
CS123	<---	PC1234	,233	,046	5,028	***	par_28
CS123	<---	EF1234	,093	,048	1,962	,050	par_29
CS123	<---	TI1234	,227	,054	4,173	***	par_30

Squared Multiple Correlations: (Group number 1 - Default model)

	Estimate
CS123	,600
CS1	,932
CS2	,962
CS3	,949
TI4	,555
TI2	,543
TI1	,573
TI3	,560
EF1	,539