

Explaining and Predicting Public Transportation Adoption Among Female University Students in Saudi Arabia: A TAM and Machine Learning Approach

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Abstract—Public transportation is important to sustainable mobility in Saudi Arabia, but adoption among female university students remains underexplored. This study examines behavioral intention using an extended Technology Acceptance Model comprising perceived usefulness, perceived ease of use, perceived safety, privacy and comfort, social influence, service quality, perceived affordability, and environmental concern. PLS-SEM was used to examine associations with behavioral intention, while logistic regression, random forest, and support vector machines explored patterns associated with current public-transportation use. The model explained 79.3% of the variance in behavioral intention ($R^2 = 0.793$). Perceived safety had the largest positive path coefficient ($\beta = 0.457$; $f^2 = 0.283$). Logistic regression achieved the highest reported cross-validated ROC-AUC (0.756). The findings are exploratory and require cautious interpretation given the sample and discriminant-validity limitations.

Keywords—Public transportation; machine learning; technology acceptance model TAM; PLS-SEM; data-driven computational approaches; sustainable mobility

I. INTRODUCTION

Saudi Arabia has historically been highly dependent on private vehicles, while public transportation has developed more recently as part of the country's transition toward more sustainable urban mobility. Rapid urbanization, urban sprawl, and automobile dependence have increased congestion, energy use, and environmental challenges, prompting the government to expand public and sustainable transportation under Vision 2030 [1]. Major investments in public transportation and integrated mobility systems are intended to provide more efficient and sustainable alternatives to private-car travel.

This transformation is particularly relevant to women's mobility in Saudi Arabia. Historically, Saudi women faced significant mobility constraints because of limited access to independent transportation and the relatively limited availability of affordable, accessible public transportation. Before women were permitted to drive in 2018, mobility often depended on family members, private drivers, taxis, or other shared transportation. Although the driving reform substantially expanded women's mobility options, greater access to private vehicles does not necessarily shift them toward public transportation. Al-Garawi and Kamargianni's large-scale study of 20504 Saudi women found that a substantial proportion changed their primary mode of transportation after the reform,

with 37.7% reporting that they switched to using a household private car as a driver [2]. These findings suggest that expanding women's mobility opportunities and reducing dependence on private vehicles are related but distinct objectives.

Despite these changes, research indicates that Saudi women remain interested in sustainable mobility when appropriate alternatives are available. Studies have identified accessibility, safety, privacy, connectivity, affordability, service quality, and the availability of suitable transportation alternatives as important factors shaping women's travel behavior [3, 4]. In the Dammam Metropolitan Region, Al-Rashid et al. [5] found that limitations in routes, operating hours, infrastructure, and gender-responsive design affected women's public transportation experiences, while privacy and security were particularly important for women traveling alone or with children. Albadawi and Farag [4] investigated changes in young Saudi women's travel behavior between 2015 and 2020 using Jeddah as a case study. The authors reported that the private car remained the dominant mode of mobility despite women expressing willingness to shift toward more sustainable transportation modes when appropriate alternatives were available.

These issues are particularly relevant to female university students, who represent a distinctive group of transport users. University students typically make regular trips between their homes and campuses according to relatively fixed academic schedules. Their travel choices may therefore depend on factors such as travel distance, journey time, service availability, affordability, access to a private vehicle, driving-licence status, and previous experience with public transportation. For female students, additional considerations may include personal safety, privacy, comfort, and the availability of transportation services that are appropriate to their needs [6]. Consequently, examining female university students separately from the broader population of Saudi women can provide a better understanding of the factors shaping educational travel. The importance of transportation for female students in Saudi Arabia has been documented for many years. Al-Ahmadi [7], for example, examined the travel characteristics of female students travelling to colleges in Saudi Arabia and reported that many students travelled long distances and depended on others for transportation, creating difficulties related to travel time, cost, convenience, and the quality of vehicles and drivers. More recent research shows that these mobility challenges have

evolved as women's transportation opportunities have changed. In Riyadh, Aldaham and Alzeer [8] examined the quality and satisfaction of university transportation services among female students at King Saud University, highlighting the importance of service quality in the university transportation experience.

Safety is another important consideration. Research on gender-responsive transportation in Saudi Arabia has identified security as one of the most important aspects of women's public-transport experiences [9]. This is particularly relevant for female students because their journeys involve repeated travel between residential areas and campuses, including access to stations or bus stops, waiting times, boarding, the journey itself, and the final connection to the university. Thus, simply providing public transportation may not be sufficient to encourage its adoption; female students must also perceive the service as safe.

Privacy and comfort represent another potentially important dimension. Al-Rashid et al. [5] found that privacy was an important consideration for women in the Dammam Metropolitan Region, including the absence of dedicated spaces or appropriate arrangements for female passengers and privacy concerns at waiting areas. For female students, the perceived quality of the physical and social travel environment may also affect their willingness to adopt public transportation.

Affordability is similarly relevant. Previous research on female travelers has identified affordability among factors associated with women's choices. Therefore, even if students perceive public transportation as safe and convenient, relatively high fares or an absence of student-oriented pricing could reduce their willingness to use the service regularly.

At the same time, service quality may determine whether public transportation is perceived as a realistic alternative to private vehicles. Service frequency, reliability, cleanliness, accessibility, route coverage, and operating hours can influence users' perceptions of the practicality of public transportation. Evidence from the Dammam Metropolitan Region indicates that limited routes, operating hours, and infrastructure were among the weaknesses of existing public transportation services identified by respondents. For university students, these characteristics are particularly important because academic schedules often require predictable arrival and departure times.

Beyond these transport-specific factors, social influence may also be relevant. This may be particularly relevant for young female students whose transportation arrangements can involve family members. If important social groups perceive public transportation positively, students may become more willing to consider it as a normal and acceptable mode of university travel. Environmental considerations provide an additional rationale for examining public transportation adoption. Saudi research has increasingly examined green mobility and sustainable transportation as mechanisms for improving environmental outcomes and quality of life. The transition toward more sustainable urban mobility therefore requires not only the provision of infrastructure but also an understanding of users' willingness to change their travel behavior.

These considerations provide a strong basis for applying and extending the Technology Acceptance Model (TAM).

Originally proposed by Davis [10], TAM suggests that perceived usefulness and perceived ease of use are central determinants of users' acceptance of technology.

However, relying only on the original TAM constructs may provide an incomplete explanation of public transportation adoption among Saudi female university students. Public transportation involves a physical and social environment in which safety, privacy, affordability, service quality, and social acceptance may be particularly important [6]. Therefore, this study extends TAM by incorporating perceived safety, privacy, and comfort, social influence, service quality, perceived affordability, and environmental concern alongside perceived usefulness and perceived ease of use.

PLS-SEM is useful for identifying the overall factors that influence public transportation adoption. However, it generally describes relationships at the sample level and may not fully capture differences between individual students. For example, some students may depend heavily on private cars and have limited interest in public transportation, whereas others may already use buses or metro services and consequently have more positive perceptions of public transportation. A third group may rarely use public transportation but may be willing to change their travel behavior when factors such as congestion, fuel costs, parking difficulties, or travel time become more burdensome. Treating these students as a homogeneous group may therefore provide an incomplete understanding of public transportation adoption among female university students.

To address this issue, PLS-SEM can be complemented by machine-learning techniques that can capture individual-level patterns and differences. Recent studies have demonstrated the growing application of machine-learning techniques in public transportation research. Alexandre et al. [11], in a systematic review, identified applications including travel-time prediction, passenger-flow prediction, bus-delay estimation, service reliability, and passenger-information improvement. Similarly, Jevinger et al. [12] showed that artificial intelligence has increasingly been applied to demand prediction, traffic and travel-time forecasting, operational planning, passenger-flow analysis, and service optimization. However, much of this research has focused on transportation operations and system performance rather than individual-level adoption behavior. This study addresses this gap by applying machine-learning classification to female university students' transportation data to identify patterns associated with public transportation use. By combining PLS-SEM with classification techniques, the study can examine both the theoretical relationships among the proposed constructs and the ability of these factors, together with relevant travel characteristics, to distinguish students who use public transportation from those who rely on other transportation modes. The remainder of this study is organized as follows. Section II reviews the relevant literature, presents the extended TAM framework, and develops the study hypotheses. Section III describes the research design, sample, measurement instrument, and analytical procedures. Section IV presents the PLS-SEM measurement and structural model results together with the machine-learning classification results. Section V discusses the findings and their theoretical and practical implications. Finally, Section VI concludes the study,

summarizes its main contributions and limitations, and identifies directions for future research.

II. LITERATURE REVIEW AND HYPOTHESES

A. Public Transportation and Female University Students in Saudi Arabia

Public transportation is a key part of sustainable urban mobility, as it can provide an alternative to private vehicle use, provide access to education and job opportunities, and contribute to the efficient use of city transport infrastructure. The development of public transport in Saudi Arabia has become increasingly important with rapid urbanization, high levels of reliance on private vehicles, and an ever-increasing need for sustainable mobility options. Public transport availability and quality can impact people's willingness to change their travel behaviors and reduce reliance on private vehicles. Halawani and Rehim [13] observed in Medina that 53% of people are prepared to switch to public transportation when it becomes available. They also observed that previous public transport experience and other individual characteristics were associated with intention of changing.

This is especially relevant for women because mobility decisions depend not only on conventional transport attributes such as travel time and cost but also on safety, privacy, comfort, access, and the transport infrastructure. Al-Rashid et al. [5] explored gender-responsive public transportation in the Dammam Metropolitan Region and found that public transport use was adversely affected by lack of routes, operating hours, and infrastructure. They also found privacy, insecurity, and lack of gender-responsive design in women's mobility as some of the issues that matter.

There is also research on young Saudi women that has shown the necessity of providing suitable mobility alternatives. Al-Rashid et al. [5] reported on changes in travel habits of young Saudi women in Jeddah between 2015 and 2020. The private car was still the preferred mode of transportation, but many of the respondents were in favor of sustainable modes if alternatives were available. The lack of mobility networks and alternative transportation options was identified as a key obstacle to sustainable mobility.

University students are very relevant in this case. Daily travel to and from university is always a need, so the perception of safety, convenience, affordability, accessibility, and service quality may be a factor that influences transportation. Female university students have mobility requirements that are different from those of the overall population because their travel needs are associated with class schedules, campuses and residential areas, family transport and transport services. If one looks at this population separately, we are able to better understand why they are planning to take public transport.

B. Technology Acceptance Model, Perceived Usefulness and Perceived Ease of Use

Davis [10] developed TAM to help users form acceptance intentions towards technology. The original model identifies two main perceptions: perceived usefulness (PU) and perceived ease of use (PEOU). PU refers to the extent of the perception of the user that using public transportation will make travel to

university easier. Public transportation is useful for female university students when it facilitates access to university, reduces the effort of commuting, provides reliable transportation for getting to the university, and is a practical alternative to family members, private vehicles, or other forms of transport. For female university students, usefulness may be especially relevant if public transportation can meet the needs of university travel. A service that offers convenient connections to campus, predictable travel times, and sufficient availability may be more useful than a service that is difficult to integrate into students' daily schedules. Accordingly:

H1: Perceived usefulness positively influences Saudi female university students' intention to use public transportation.

PEOU is the extent to which students believe that public transportation can be used without significant physical, cognitive, or procedural effort. In this work, ease of use refers to easy-to-find routes, accessible stations, convenient payment systems, and user-friendly digital services that reduce the effort associated with public transport use. Therefore:

H2: Perceived ease of use positively influences Saudi female university students' intention to use public transportation.

C. Perceived Safety

Perceived safety refers to the degree to which students feel safe on a public transportation journey. Safety is especially relevant to female mobility. Al-Rashid et al. [5] found that women's public transport experience in the Dammam Metropolitan Region was affected by issues related to insecurity and the adequacy of gender-responsive transport infrastructure. The study highlighted the necessity for developing public transportation systems that are gender-responsive to women's mobility needs. Therefore, safety is incorporated as a transportation-specific extension of TAM:

H3: Perceived safety positively influences Saudi female university students' intention to use public transportation.

D. Privacy and Comfort

Research on women's transportation in Saudi Arabia supports the importance of privacy. Al-Rashid et al. [5] identified privacy and insecurity as the two main concerns women have with public transportation. Comfort may also affect students' willingness to use public transportation for longer trips to university. A daily commute can be a lot of waiting time and travelling, so uncomfortable vehicles, insufficient seating, or poor facilities might reduce the appeal of public transportation. For female university students, privacy and comfort may therefore be very important experiential characteristics of the service. Accordingly:

H4: Privacy and comfort positively influence Saudi female university students' intention to use public transportation.

E. Social Influence

Transportation choices are not made entirely independent of the social environment. This is particularly relevant in the Saudi context, where family and social relationships may affect travel and mobility decision-making. Research on young Saudi women has indicated changes in the social dimension of mobility and found that social factors can support the adoption of sustainable

mobility modes. For female university students, public transportation acceptance may in part depend on whether the mode is socially accepted and perceived as appropriate by significant others. Therefore:

H5: Social influence positively influences Saudi female university students' intention to use public transportation.

F. Service Quality

Service quality is students' assessment of the operational and functional characteristics of public transportation. In this study, it covers reliability, cleanliness, maintenance, service frequency, and the overall quality of the transportation experience. Service quality is extremely important because a positive attitude towards public transportation may not translate into intention if the actual service does not satisfy users' practical needs. Al-Rashid et al. [5] found that the lack of routes, operating hours, and infrastructure in public transportation areas in the Dammam Metropolitan Region was one of the major weaknesses of public transportation. A reliable and accessible service can therefore boost students' confidence that public transportation can meet their daily university travel needs. Hence:

H6: Service quality positively influences Saudi female university students' intention to use public transportation.

G. Perceived Affordability

As a student, perceived affordability refers to how well students perceive public transportation as financially feasible in relation to their financial resources and the transportation costs of other transport options. For university students, the cost is especially important as many students have family financial support, allowances, and less money to live on and pay. The price of public transportation can therefore affect its perception as a feasible alternative to private vehicles, taxis, ride-hailing services, and private drivers. Halawani and Rehim [13] also studied the effects of the public transportation shift in Saudi Arabia, showing that changes in modal shift have both individual and systemic economic implications. For female university students, the low fares, student discounts, and predictable costs of public transportation are expected to be affordable, making it a reasonable option for transportation. Consequently:

H7: Perceived affordability positively influences Saudi female university students' intention to use public transportation.

H. Perceived Environmental Concern

Transportation is heavily associated with energy consumption, emissions, and the environmental impacts of cities. The transition from private vehicles to more sustainable modes is therefore key to sustainable mobility. In the context of Saudi Arabia, Al-Rashid et al. [5] highlighted the sustainability implications of heavy reliance on private vehicles and how public transportation can play a role in promoting sustainable mobility. Young Saudi women are willing to embrace sustainable modes if such alternative options are available [5]. Environmental concern could therefore complement the utilitarian aspects of TAM. Students may prefer public transportation, not just because it is convenient or inexpensive

but because it is seen as a more environmentally friendly mode of transportation. Therefore:

H8: Environmental concern positively influences Saudi female university students' intention to use public transportation.

I. Behavioral Intention to Use Public Transportation

Behavioral intention is the student's intention or desire to use public transportation for university-related travel. In TAM, behavioral intention is an important proximal indicator of technology or service acceptance. Davis [10] found that acceptance perceptions were related to the intention of future use. In transportation research, intention to shift toward public transportation has also been studied as an important indicator of modal change. Halawani and Rehim [13] investigated commuters' initial intentions to shift to public transportation in Medina and found that a significant proportion of respondents expressed willingness to shift when public transportation becomes available. In this study, behavioral intention is considered to be a representation of female university students' willingness to use public transportation for university travel. The conceptual relationships we consider are summarized in Fig. 1.

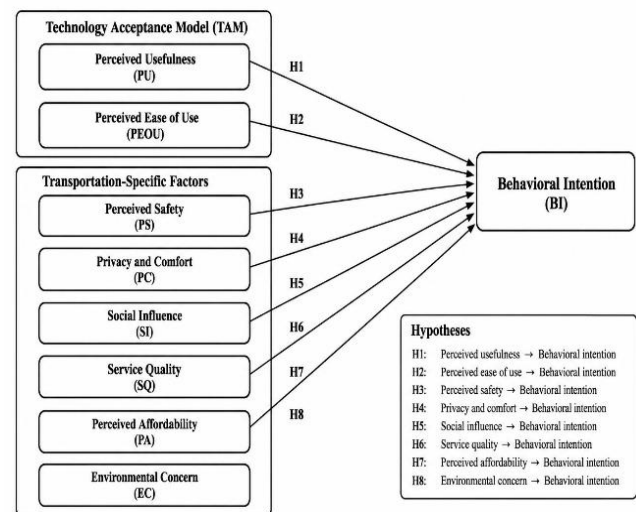


Fig. 1. Model constructs.

J. Heterogeneity and Machine Learning

The preferences of female students may vary according to vehicle ownership, driving license, previous public transportation experience, travel distance, etc. Therefore, treating all students as a unifying group may mask some of the important differences in the factors which influence public transportation use. Travel behavior segmentation studies have shown that residents can be classified according to their attitude towards private vehicles, environmental concerns, and the motivation to change their travel behavior [14]. Machine learning can also help to identify and predict these differences. Alexandre et al. in their systematic literature review [11] investigated the application of machine learning in bus-based public transportation and found that existing studies have addressed many operational and passenger-related problems of travel-time prediction, passenger-flow prediction, bus-delay

estimation, service reliability, and the improvement of passenger information for public transport. Jevinger et al. [12], a similar mapping study, also show that artificial intelligence has been applied to a wide range of public transportation activities in the fields of demand prediction, traffic and travel-time forecasting, operational planning, vehicle management, passenger-flow analysis, and service optimization. They also show that artificial intelligence can not only be used to predict but can also help to make decisions and improve public transportation services.

Although much of the literature focuses on the operational performance of bus systems rather than individual adoption intentions, its findings are relevant for the current study. However, service improvement is also important for female students who are experiencing frequent traffic congestion and who are considering moving from private vehicles to public transport. Alexandre et al. [11] support the potential of machine learning as a complementary tool to investigate public transportation and also point out that some passenger-related and adoption-oriented problems have not yet been investigated.

In this work, machine learning is going to complement the explanatory analysis of Structural Equation Modeling (SEM) that was done. The study proposes using SEM to study the hypotheses discussed in the previous section. Machine learning classification models will be used to predict whether a female student will be on or off public transportation. The two combined methods provide two sources of knowledge. SEM explains the theoretical relationship between constructs, while machine learning is used to predict and identify heterogeneous behavior profiles. By combining theory-based modeling with predictive and segmentation methods, the study can give a better understanding of the adoption of public transportation by Saudi residents.

III. METHODOLOGY

A. Research Design and Sample Characteristics

This study adopted a quantitative cross-sectional survey design. 119 responses from female students were collected from 1 January 2026 to March 2026. Respondents reported university type, academic level, academic discipline, residence, distance to university, travel time, current transport mode, driving license status, transportation expenditure, and personal income/allowance. The questionnaire contains five measurement items for all eight predictors and five items for behavioral intention, measured on a five-point Likert scale from strongly disagree (1) to strongly agree (5).

The sample had 119 female respondents, with the largest age group being 21-23 years (77; 64.7%) and 18-20 years (30; 25.2%). Public university students were 109 of the 119 respondents (91.6%). Fourth-year students (59; 49.6%) were the largest academic group, and fifth-year or higher students (27; 22.7%) were the next largest. Business and management dominated the group (76; 63.9%). Most respondents lived with their families (110; 92.4%).

There are relatively large commuting requirements: 64 respondents (53.8%) lived more than 30 km from the university. The most common travel times were 31-45 minutes (31; 26.1%) and 46-60 minutes (27; 22.7%). The main modes of transport were a family member's private car (34; 28.6%), public

transportation (21; 17.6%), private driver (19; 16.0%), own private car (19; 16.0%), university bus (17; 14.3%), and taxi/ride-hailing (9; 7.6%). Ninety-four respondents (79.0%) did not have driving licenses. The study analyzed 119 valid responses from female university students. The proposed PLS-SEM model comprised nine latent constructs, measured using 45 indicators, with eight predictor constructs directly associated with behavioral intention. Sample-size adequacy was initially assessed using the commonly applied ten-times rule, which recommends a minimum sample size equal to ten times the largest number of structural paths directed toward a single endogenous construct. As behavioral intention received eight incoming paths, the minimum sample size under this heuristic was 80 respondents. Therefore, the sample of 119 exceeded this preliminary requirement. Consequently, the sample is considered sufficient under the ten-times heuristic.

B. Ethical Considerations

This study involved a cross-sectional survey of 119 female university students in Saudi Arabia. Participation was voluntary, and respondents were informed about the study's objectives, the intended use of their responses, and their right to decline participation or withdraw before submitting the questionnaire. The survey data were collected anonymously, and access to the dataset was restricted to the research team. The information was used exclusively for academic research purposes and analyzed in aggregate form to protect participants' privacy.

C. Measurement and Analysis

The measurement items were designed to account for both TAM factors and transportation factors in relation to female university students. PU and PEOU are the basic technology acceptance perceptions; PS and PC are safety, privacy, and comfort aspects. SI is the effect of family, friends, colleagues, and other important people, and SQ is service reliability, frequency, cleanliness, accessibility, and overall travel quality. PA is the price of public transportation, and EC is an environmental factor related to sustainable mobility. Finally, BI is the dependent construct and measures students' willingness and intention to use public transportation for university-related travel. Each construct was measured using five items, resulting in 45 measurement items. All items were assessed using a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree.

D. Machine-Learning Classification

To complement the PLS-SEM analysis, we conducted an exploratory supervised machine-learning analysis to distinguish current public-transportation users from non-users. Unlike the PLS-SEM model, which examines behavioral intention as the dependent construct, the classification models focus on respondents' reported current transportation behavior. This distinction allows the study to examine two related but different dimensions of public-transportation adoption.

The classification analysis considered the eight explanatory constructs included in the extended TAM framework, together with selected demographic and travel-related characteristics. We excluded behavioral intention from the predictor set to distinguish the explanatory and classification analyses. Three classification algorithms were evaluated: logistic regression,

random forest, and support vector machine (SVM). Model performance was assessed using stratified five-fold cross-validation to preserve the relative distribution of users and non-users across the evaluation folds.

The dataset contained 38 respondents classified as public-transportation users and 81 as non-users, corresponding to an imbalanced binary classification problem. Accordingly, performance was evaluated using accuracy, balanced accuracy, F1-score, and ROC-AUC rather than accuracy alone. The following table gives the Model configuration table completed based on the classification process conducted on the dataset of 119 female university students.

TABLE I. MODEL CONFIGURATION FOR MACHINE LEARNING

Component	Configuration
Sample size	119 observations
Classification target	Current public-transportation use (binary classification)
Class distribution	38 users (32.0%); 81 non-users (68.0%)
Cross-validation	Stratified five-fold cross-validation, with shuffling and random seed = 42
Categorical encoding	One-hot encoding with the first category dropped (drop_first=True)
Missing-value treatment	Median imputation within the model pipeline
Feature scaling	StandardScaler for logistic regression and SVM; no scaling for random forest
Logistic regression	Solver: lbfgs; L2 regularization (default); C = 1.0; maximum iterations = 2,000; class weight = balanced
Random forest	Number of trees = 500; maximum depth = 4; minimum leaf size = 4; maximum features = sqrt; class weight = balanced; random seed = 42
SVM	Kernel = RBF; C = 1.0; gamma = scale; probability estimation enabled; class weight = balanced; random seed = 42
Class-imbalance treatment	Class-weighted learning (class_weight='balanced') for all three models; no resampling applied
Evaluation metrics	Accuracy, balanced accuracy, F1-score, and ROC-AUC

Table I summarizes the preprocessing procedures, model hyperparameters, class-imbalance treatment, and evaluation settings adopted in the machine-learning analysis. The classification models were developed using 119 observations and evaluated through stratified five-fold cross-validation. Categorical predictors were transformed using one-hot encoding, missing numerical values were handled through median imputation, and feature standardization was applied to logistic regression and support vector machine models. Class-weighted learning was employed to address the unequal distribution of public-transportation users and non-users. In addition, a robustness analysis excluding university-bus users was specified to examine the sensitivity of the classification results to the definition of public-transportation use.

IV. RESULTS

A. Measurement Model Using PLS-SEM

1) *Reliability and convergent validity*: The reliability and convergent validity of the measurement model were evaluated

using Cronbach's alpha, the composite reliability (rho_A and rho_C), and average variance extracted (AVE). As shown in Table II, Cronbach's alpha values ranged from 0.850 for EC and PEOU to 0.930 for BI. This is well above the common standard of 0.70, and we can see that all constructs had satisfactory internal consistency. Similarly, rho_C also ranged from 0.893 to 0.947, and we can see that the constructs were also consistent. The rho_A values ranged from 0.864 to 0.966.

Convergent validity was checked using AVE. All constructs exceeded the recommended level of 0.50, with AVE between 0.626 and 0.782 for EC and BI. This means that each of the constructs explains more than half of the variance in its indicators, and therefore convergent validity is good.

TABLE II. ASSESSMENT OF MEASUREMENT MODEL RELIABILITY AND CONVERGENT VALIDITY USING CRONBACH'S ALPHA, RHO_A, RHO_C, AND AVERAGE VARIANCE EXTRACTED

	Cronbach's alpha	rho_a	rho_c	AVE
BI	0.930	0.930	0.947	0.782
EC	0.850	0.864	0.893	0.626
PA	0.920	0.923	0.940	0.759
PC	0.894	0.966	0.913	0.679
PEOU	0.850	0.876	0.894	0.632
PS	0.904	0.909	0.929	0.723
PU	0.919	0.942	0.939	0.758
SI	0.860	0.877	0.901	0.648
SQ	0.895	0.904	0.923	0.705

2) *Discriminant validity*: Discriminant validity was assessed using the Fornell–Larcker criterion in Table III and HTMT in Fig. 2. Table III shows that the Fornell–Larcker criterion was not satisfied for the SI–SQ pair: their correlation (0.849) exceeded the square roots of AVE for SI (0.805) and SQ (0.840). The HTMT value for SQ–SI (0.958) corroborated this concern. Thus, discriminant validity was not fully established.

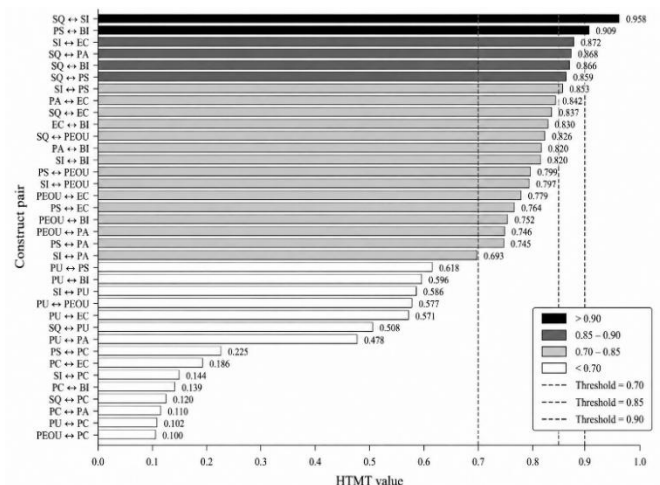


Fig. 2. Assessment of discriminant validity among the study construct pairs using the heterotrait–monotrait ratio criterion.

TABLE III. ASSESSMENT OF DISCRIMINANT VALIDITY AMONG THE STUDY CONSTRUCTS USING THE FORNELL-LARCKER CRITERION

	BI	EC	PA	PC	PEOU	PS	PU	SI	SQ
BI	0.884								
EC	0.748	0.791							
PA	0.763	0.749	0.871						
PC	0.137	0.167	0.071	0.824					
PEOU	0.678	0.667	0.668	0.055	0.795				
PS	0.837	0.682	0.689	0.221	0.705	0.850			
PU	0.561	0.508	0.453	0.068	0.517	0.574	0.871		
SI	0.736	0.756	0.626	0.093	0.685	0.756	0.523	0.805	
SQ	0.796	0.735	0.791	0.098	0.735	0.780	0.471	0.849	0.840

However, a more cautious interpretation emerges from the HTMT results reported in Fig. 2. Most HTMT values were below 0.90, indicating adequate distinction between the corresponding constructs. Nevertheless, PS-BI reached 0.909 and SQ-SI reached 0.958, exceeding the 0.90 threshold. The latter represents the clearest discriminant-validity concern in the model and indicates substantial empirical overlap between service quality and social influence.

Several additional relationships were below 0.90 but above the more conservative threshold of 0.85, including SI-EC (0.872), SI-PS (0.853), SQ-BI (0.866), SQ-PA (0.868), and SQ-PS (0.859). Therefore, the Fornell-Larcker criterion and HTMT both indicate inadequate discriminant validity for SQ and SI; discriminant validity is not fully established across the measurement model.

B. Structural Model

The structural model results are presented in Fig. 3 and 4, and the following structural-model tables. The standardized path coefficients shown in Fig. 3 indicate the direction and relative magnitude of the relationships between the eight predictor constructs and behavioral intention. The results reveal substantial variation in the strength of the associations across the predictors.

The path model showed differences in the magnitude and direction of the relationships. PS showed the strongest positive association with behavioral intention ($\beta = 0.457$), indicating that higher perceptions of safety were associated with stronger intentions to use public transportation.

Perceived affordability (PA $\rightarrow$ BI: $\beta = 0.181$), service quality (SQ $\rightarrow$ BI: $\beta = 0.176$), and environmental concern (EC $\rightarrow$ BI: $\beta = 0.172$) also had positive associations with behavioral intention, although their coefficients were much smaller than perceived safety. Perceived usefulness had a weak positive relationship with behavioral intention (PU $\rightarrow$ BI: $\beta = 0.074$).

Privacy and comfort (PC $\rightarrow$ BI: $\beta = -0.025$), perceived ease of use (PEOU $\rightarrow$ BI: $\beta = -0.039$), and social influence (SI $\rightarrow$ BI: $\beta = -0.012$) had very small negative path coefficients. The

magnitude of these coefficients was close to zero, demonstrating only limited unique associations with behavioral intention when the other predictors were included simultaneously in one model.

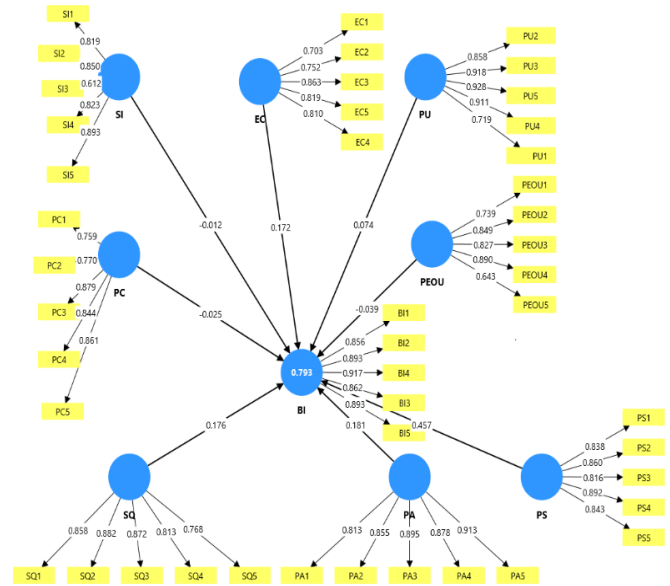


Fig. 3. Standardized path coefficients of the PLS-SEM structural model predicting behavioral intention to use public transportation.

The path coefficients are consistent with the effect size results. PS had the largest effect size ($f^2 = 0.283$), while EC and PA had small effects ($f^2 = 0.041$), followed by SQ ($f^2 = 0.023$). PU had a very small effect ($f^2 = 0.016$), PC and PEOU each had negligible effects ($f^2 = 0.003$), and SI had virtually no unique effect ($f^2 = 0$).

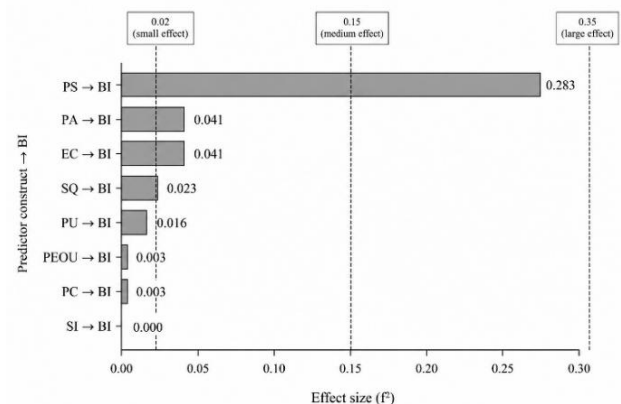


Fig. 4. f-square (f^2) of the predictor constructs on behavioral intention in the PLS-SEM structural model.

TABLE IV. EXPLANATORY POWER OF THE STRUCTURAL MODEL FOR BEHAVIORAL INTENTION BASED ON R^2 AND ADJUSTED R^2 VALUES

	R-square	R-square adjusted
BI	0.793	0.778

Table IV shows that the model explained 79.3% of the variance of behavioral intention ($R^2 = 0.793$; adjusted $R^2 = 0.778$). Thus, the eight predictors in the structural model explained 79.3% of the variance in behavioral intention. This

indicates a large explanatory capacity for BI in the sample. The effect sizes (f^2) give us a closer look at the value of each predictor's contribution to the variance of BI. The results are quite different for different predictors. Perceived safety had the largest effect ($f^2 = 0.283$), which is medium, according to the commonly used PLS-SEM guidelines. EC and PA had relatively small effects ($f^2 = 0.041$), and SQ also showed a small effect ($f^2 = 0.023$). PU showed an effect size of 0.016, below the standard 0.02 threshold for a small effect. PC and PEOU had very small effects ($f^2 = 0.003$), while SI had an effect size around 0.

C. Hypothesis Testing Using Bootstrapping

Hypotheses H1–H8 were evaluated using the SmartPLS 4 bootstrapping output. Table V reports standardized path coefficients, t-statistics, p-values, and percentile 95% confidence intervals. At the 5% significance level, only perceived safety (H3) was supported; the other seven paths were not statistically significant.

TABLE V. BOOTSTRAP HYPOTHESIS TESTING RESULTS (95% PERCENTILE CONFIDENCE INTERVALS)

Hyp.	Path	β	t	p	95% CI	Decision
H1	PU $\rightarrow$ BI	0.074	1.439	0.150	[-0.027, 0.175]	Not supp.
H2	PEOU $\rightarrow$ BI	-0.039	0.296	0.767	[-0.286, 0.218]	Not supp.
H3	PS $\rightarrow$ BI	0.457	3.692	<0.001	[0.182, 0.674]	Yes
H4	PC $\rightarrow$ BI	-0.025	0.375	0.708	[-0.144, 0.118]	Not supp.
H5	SI $\rightarrow$ BI	-0.012	0.086	0.932	[-0.260, 0.302]	Not supp.
H6	SQ $\rightarrow$ BI	0.176	0.914	0.361	[-0.263, 0.483]	Not supp.
H7	PA $\rightarrow$ BI	0.181	1.203	0.229	[-0.074, 0.512]	Not supp.
H8	EC $\rightarrow$ BI	0.172	1.198	0.231	[-0.074, 0.484]	Not supp.

D. Structural-Model Collinearity Assessment

Inner-model collinearity was evaluated using variance inflation factors (VIF) for the eight predictors of behavioral intention. As reported in Table VI, SI (VIF = 5.195) and SQ (VIF = 6.527) exceed the commonly used threshold of 5, indicating potentially problematic collinearity. The other predictors have VIF values between 1.121 and 3.847. The elevated SI and SQ values, together with their Fornell–Larcker and HTMT results, indicate substantial construct overlap. Thus, the near-zero SI coefficient ($\beta = -0.012$), despite its correlation with BI ($r = 0.736$), cannot establish that social influence is unimportant. SQ and SI are retained as theoretically distinct constructs in the present exploratory model, but their individual coefficients warrant caution.

TABLE VI. INNER-MODEL COLLINEARITY STATISTICS FOR PREDICTORS OF BEHAVIORAL INTENTION

Predictor	VIF	Predictor	VIF
PU	1.625	PEOU	2.637
PS	3.579	PC	1.121

SI	5.195	SQ	6.527
PA	3.847	EC	3.537

E. Classification Results

In addition to the PLS-SEM analysis, the study conducted a supervised machine learning classification analysis to identify whether individual-level characteristics and study variables could distinguish female university students who currently use public transportation from those who use other modes of transportation. Public transportation and university bus users were classified as public-transportation users, while students who use private cars, family vehicles, private drivers, or taxi/ride-hailing services were classified as non-public-transportation users. Logistic regression, random forest, and support vector machine classifiers were performed with stratified five-fold cross-validation. The performance of the models was evaluated based on accuracy, balanced accuracy, F1-score, and the area under the receiver operating characteristic curve (ROC-AUC). Because the sample size and the group imbalance were small, we treated the classification results as exploratory and interpreted them as a step forward to the PLS-SEM results.

The predictors were: PU, PEOU, PS, PC, SI, SQ, PA, EC, distance to university, travel time, and driving license status. BI was not included in this classification, so intention is not used to predict a closely related behavioral outcome.

TABLE VII. PERFORMANCE COMPARISON OF SUPERVISED MACHINE LEARNING MODELS FOR PREDICTING CURRENT PUBLIC-TRANSPORTATION USE

Classification model	Accuracy	Balanced Accuracy	F1	ROC-AUC
Logistic Regression	72.2%	70.5%	0.594	0.756
Random Forest	69.7%	64.8%	0.507	0.739
SVM	67.1%	65.0%	0.529	0.734

The results in Table VII show that the survey variables contain some predictive information about current public-transportation use, with the logistic model producing a cross-validated ROC-AUC of approximately 0.756. However, because the sample is relatively small and the two classes are unbalanced (38 vs 81), these results are presented as exploratory evidence, not as definitive evidence of generalizable predictive performance.

V. DISCUSSION

The extended structural model explained 79.3% of the variance in behavioral intention ($R^2 = 0.793$). The eight predictors were perceived usefulness, perceived ease of use, perceived safety, privacy and comfort, social influence, service quality, perceived affordability, and environmental concern. However, their estimated contributions differed considerably, with perceived safety exhibiting the strongest positive association with behavioral intention.

The most prominent structural relationship was with respect to perceived safety, which had the largest positive path coefficient ($\beta = 0.457$) and the largest effect size ($f^2 = 0.283$). In the model, respondents who perceived public transportation as

safer also had stronger behavioral intentions to use it. The magnitude of this relationship indicates that safety is of particular relevance to explain public transport intentions in the population we surveyed. From a practical point of view, better perceptions of passenger safety, security, station environments and overall travel experience may therefore be important when encouraging public transport use.

In fact, the results also showed that BI was positively associated with perceived affordability ($\beta = 0.181$), service quality ($\beta = 0.176$) and environmental concern ($\beta = 0.172$). However, their effect sizes were very small compared to safety. Affordability produced $f^2 = 0.041$, which means that affordable public transport services make a small unique contribution to the reason for behavioral intention. Environmental concern had the same effect size ($f^2 = 0.041$) and therefore environmental considerations may also play a role in intention, but their contribution is very small after the other factors are taken into account.

Service quality was also positive ($\beta = 0.176$) with a small effect size ($f^2 = 0.023$). However, this relationship is to be interpreted with caution since the HTMT value between SQ and SI was 0.958, meaning they are not able to discriminate between them under the standard 0.90 criterion, and the large overlap between SQ and SI would impact the estimation and interpretation of the structural effects.

Perceived usefulness showed a weak positive path coefficient ($\beta = 0.074$, $f^2 = 0.016$). Although perceived usefulness is central to TAM-based explanations of behavioral intention, its unique contribution in the extended model was limited after accounting for perceived safety, privacy and comfort, perceived affordability, service quality, social influence, environmental concern, and perceived ease of use. This does not necessarily imply that usefulness is unimportant; rather, its estimated unique association with behavioral intention was small when the other predictors were included.

The estimated path coefficients for privacy and comfort (PC $\rightarrow$ BI: $\beta = -0.025$), perceived ease of use (PEOU $\rightarrow$ BI: $\beta = -0.039$), and social influence (SI $\rightarrow$ BI: $\beta = -0.012$) were all close to zero, with corresponding effect sizes of $f^2 = 0.003$, 0.003, and 0.000, respectively. These small negative coefficients should not be interpreted as evidence that higher levels of privacy and comfort, perceived ease of use, or social influence reduce behavioral intention. Instead, they indicate negligible unique associations with behavioral intention after accounting for the other predictors in the structural model. In particular, SI has a substantial bivariate correlation with BI ($r = 0.736$), but its adjusted path is near zero. Given the high SQ-SI overlap and elevated inner VIF values, this result may reflect shared variance among predictors rather than the irrelevance of social influence.

Measurement-model studies provide additional context to these relationships. The internal consistency and convergent validity were satisfactory, as all constructs have higher reliability and AVE. However, the HTMT assessment revealed some discriminant validity concerns. SQ-SI was found to have an HTMT of 0.958, and PS-BI was 0.909. Several of the relationships were more than 0.85. Thus, although the measurement model is well tested in terms of reliability and

convergent validity, the distinction between some constructs is not so clear. That is particularly true when we consider the relatively strong PS $\rightarrow$ BI coefficient and the separate contributions of SQ and SI. Inner-model VIF values reinforce this concern: SI (5.195) and SQ (6.527) exceed 5, whereas the remaining predictors range from 1.121 to 3.847. Consequently, the individual SI and SQ coefficients may be unstable, and their separate effects should not be interpreted as definitive.

VI. CONCLUSION

This study investigated the use of public transportation by female university students in Saudi Arabia by integrating an extended Technology Acceptance Model with PLS-SEM and exploratory machine learning classification. This expanded model also included perceived usefulness, perceived ease of use, perceived safety, privacy and comfort, social influence, service quality, perceived affordability, and environmental concern to provide a more holistic explanation of behavioral intention than the traditional TAM constructs alone.

The model explained 79.3% of the sample variance in behavioral intention. Perceived safety had the largest positive coefficient ($\beta = 0.457$; $f^2 = 0.283$). Perceived affordability ($\beta = 0.181$), service quality ($\beta = 0.176$), and environmental concern ($\beta = 0.172$) showed smaller positive coefficients. Perceived usefulness had a weak positive coefficient ($\beta = 0.074$), while privacy and comfort ($\beta = -0.025$), perceived ease of use ($\beta = -0.039$), and social influence ($\beta = -0.012$) were near zero. Bootstrapping showed that only perceived safety was statistically significant ($p < 0.001$); the other seven hypotheses were not supported ($p > 0.05$). Only the perceived-safety path was statistically supported by bootstrapping. The elevated VIF values for SI and SQ and their insufficient discriminant validity constrain interpretation of their separate path estimates.

The machine learning analysis provided a complementary perspective by asking if students' perceptions and travel behavior would be able to distinguish current public-transport users from non-users. Among the models investigated, logistic regression had the best exploratory performance, achieving 72.2% accuracy, 70.5% balanced accuracy, an F1-score of 0.594, and ROC-AUC of 0.756. Random forest and support vector machine models had slightly lower performance. Because of the small and imbalanced sample, these results are regarded as exploratory, not as a generalizable prediction.

There are several limitations to the results. The analysis is conducted in a relatively small, non-probability sample of 119 female university students, with a substantial concentration of public-university students and business-related disciplines. Accordingly, the findings reflect the surveyed participants rather than the broader population of female university students in Saudi Arabia.

Second, the machine-learning classification analysis involved an imbalanced distribution of 38 public-transportation users and 81 non-users. This imbalance, together with the limited sample size, may affect model stability and classification performance, particularly for the minority class. Although stratified cross-validation was employed, the predictive findings are considered exploratory and require validation using larger and more balanced independent samples in future work.

Future research should employ larger samples across multiple universities, academic disciplines, and Saudi cities to improve statistical power, sample diversity, and the external validity of the findings. The HTMT study also showed discriminant-validity issues, particularly regarding service quality and social influence, which should be considered when interpreting their separate structural relationships. We plan to use larger and more diverse samples of universities and Saudi cities in future work, looking at actual transportation behavior longitudinally and refining constructs that we find to be consistent with empirical data and validating our predictive models on other data sets. Such extensions could help us to better understand how public transportation can facilitate sustainable and inclusive university mobility opportunities in Saudi Arabia. Future analyses should examine item-level overlap between SQ and SI, refine their measurement scales, and compare theoretically justified alternative specifications, including construct consolidation where appropriate.

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