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A structural equation modeling approach to understand users' perceptions of app-based CNG auto-rickshaw services in Dhaka City

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Abstract

The use of CNG auto-rickshaws is increasing in Dhaka, the capital of Bangladesh. CNG auto rickshaws are a crucial component of the transportation system of Dhaka City. These offer the dwellers a quick and affordable way to navigate the city's congested streets. This study aims to determine how commuters in Dhaka City perceive the quality of app-based CNG auto rickshaw service. A structured questionnaire is developed based on the users' reported attitudes and perceived risks. In order to comprehend how users feel about an app-based CNG auto rickshaw service, collected data were used to create a Structural Equation (SE) model. The responses are also evaluated using the Relative Importance Index (RII) method, which validates the SE model. The study shows that women's safety and better safety experience are the most significant parameters while accepting app-based CNG auto rickshaw services. The results of this study will help the service providers involved in this operation better understand the best course of action to be taken in order to provide better service to commuters.

Keywords: App-based, CNG, Service quality, Structural equation modeling, Relative Importance Index

Introduction

The exponential expansion of the population in Dhaka City, with the escalating traffic congestion caused by unregulated vehicle density, underscores the imperative of providing adequate mobility facilities to accommodate the substantial populace. The current traffic situation calls for an additional supply of public transportation in Dhaka City. However, the unreliability of the existing public transport system can be substantiated by several factors, including overcrowding, mixing of motorized and non-motorized transport, longer waiting and travel times, insufficient stoppage, and inadequate safety measures. Regarding the safety and security conditions, the three main reasons for the dissatisfaction of passengers are unsafe driving practices, poor boarding and alighting facilities, and lack of law enforcement agencies surveillance. Reasons which make the service unsatisfactory include irregular service provided by buses, regular overcrowding,

lack of good quality buses and lack of cleanliness. The occurrence of traffic suspensions, discomfort, inadequate traffic monitoring, overcrowding, a high incidence of accidents, and air pollution problems can characterize the state of public transportation in Dhaka [1]. Moreover, the Public transit environment is not safe for women as they face sexual harassment and security threats often in Public transit [2, 3].

Current service quality scenario

In any service user perception about the quality factors is really crucial. The level of service quality directly influences the level of satisfaction among commuters and bus users. Quality of Services has a great influence on the usability and attractiveness of transport modes [4]. The quality of service has a strong and direct correlation with the perceived ease of use, particularly in terms of efficiency [5]. Over the period, many researchers identified crucial service quality factors of different transportation mediums and transportation infrastructures (i.e., Public buses, railway services, ride-sharing services, sidewalks, and foot-over bridges) [6] –[7]. Better service quality can contribute to the customer satisfaction [8]. Pasharibu et al. (2018) explored that service quality and trust significantly affected customer satisfaction [9]. Wong and Szeto, (2018) identified the service quality of any ride-sharing service as unique and hybrid as it involves not only transportation medium service quality but also the quality attained from mobile app services [10]. The capital of Bangladesh, Dhaka, is seeing a high land use pattern due to the expanding economy, which results in a huge number of trips [11]. In the current globalization scenario, the provision of public transport services requires reflective sensitivity to the SQ provided. Consequently, the examination of SQ has emerged as a crucial matter in contemporary research on public transport [12]. Researchers have measured the SQ of public transport systems using a variety of approaches over the years. Among these, customer satisfaction surveys—which are typically conducted using a questionnaire—are the method most frequently employed to find out how customers view the services [13]. According to studies, there are roughly 75 million cars on Dhaka's roads, with a road density of 65 km per 100 sq km. When motorized and non-motorized vehicles (NMV) share a road, the situation becomes more critical due to the distinct pattern of modes. Numerous studies demonstrated how users were satisfied when appealing public transport was developed. The average speed of passenger cars in Dhaka is therefore between 15 and 20 km/h. The absence of dependable public bus services and mass rapid transit increases travel times significantly [14]. Furthermore, a lack of appropriate planning techniques is evident in the 10% yearly increase in new cars that must fit into the same amount of space on the road. For most passengers in Dhaka, buses are the main mode of transportation, but the quality of the service is subpar. Despite being an essential component of any urban area, buses usually don't offer enough services to meet demand. Furthermore, the majority of the facilities are underutilised. 75% of comments in a Bashar et al. (2022) study on customer satisfaction with Dhaka City's bus service were negative or extremely negative, while 25% were positive or good [15]. In addition, the buses are not suitable, and the service is unsafe, especially for female passengers at night [16]. Rahman et al. (2020) identified factors influencing the service quality perceptions of road users including cost, time, waiting, comfort, and availability [11]. Service quality analysis conducted by Silalahi et al. (2017) found multiple components that

influence the perception of E-platform transportation facility users. perceived cognitive, perceived website innovativeness, ease of use, billing, valence, accessibility, and reliability/fulfillment were included in them [17]. Jahan (2019) explored that speed, cost, and convenience of ride influence the level of customer satisfaction of shared mobility services [18]. The main characteristics that have the greatest positive impact on the quality of shared mobility services, such as car sharing, ride hailing, and bike sharing, are comfort, cost savings, and time savings [19]. User perception of the service quality for intelligent transportation facilities was satisfactory in Taiwan [20]. Rahman, (2022) analyzed the service quality of paratransit system from female perspective and found that women who use paratransit in Dhaka City categorize safety performance movement flexibility ,expenditure and quality of drivers are the key factors that influence their perception [21]. GITHUI et al. (2009) identified level of satisfaction significantly influenced by the fare collection system [22]. Using SEM to understand the user perception, Kumar et al. (2022) found reliability is the most critical factor that influencing that influence service quality of ride-hailing service and safety is the impactful factor influence ride-sharing service quality [23].

A large portion of the population shows a propensity to use private transport (cars, motorbikes, CNG auto-rickshaws, etc.), and public transport such as buses, trams, and BRT. for their daily commute. Most people in Mega cities depend on car trips [24]. Speed, comfort, convenience, and freedom are the key factors influencing people to use private transport [18] –[20]... Additionally, Dhaka's citizens face problems of not having a personal car, where quality public transport facilities are also very fragile [25]. The living standards and well-being of individuals who do not possess an automobile experience a deterioration [26, 27]. Simultaneously rapid propagation of private cars or transport also warrants massive gridlocks. Twenty percent of private car commuters to public transport results in a 10.6% rise in average traffic speed and a 12.8% decrease in average travel delay [11]. However, a modal shift of 40% leads to a 21.0% gain in speed and a 23.2% reduction in trip delay. As a result, there exists a possibility for savings of 1.41 and 2.57 million crucial work hours. The present public transportation condition is the fundamental hindrance behind the shifting not being applicable. So, policymakers' primary concern is to provide sustainable transportation facilities that will provide convenience and safety and mitigate the current traffic conditions. Moreover, whether it is a public or private transportation system is considered the most significant source of pollution in a Country. Vehicular ownership exacerbates vehicular emissions [28].

Motor vehicles account for extreme SO_2 and NO_x emissions in Dhaka City [29, 30]. Under the air quality improvement management project (AQIM), to improve air quality in Dhaka BD, the government banned two-stroke three-wheelers and replaced them with four-stroke and compressed natural gas (CNG) engines in 2002. Until then, CNG-powered vehicles are emerging as one of Dhaka's most reliable, emission-free, and affordable private transport facilities. Other factors CNG-powered vehicles are prevalent in Bangladesh are their speed, size, and availability of fuel. Consequently, the air quality visibly improved in the capital of Bangladesh, Dhaka, after implementing programs switching the engines of three-wheeled taxis (auto-rickshaws) from two-stroke to four-stroke and increasing the use of CNG [30] [31]. CNG conversion prevented more than 2000 premature deaths, resulting in a saving of around USD 400 million [32]. Environmental benefits

of transformation ultimately compensate for the congestion cost. Still, CNG-powered vehicles have some demerits, such as "drivers not using meters, unjustified fares for short trips, longer waiting lines in front of pumps, and no parking places for these vehicles. Considering the effectiveness and good reputation among all socio-economic class different application-based Companies include CNG-powered into their Services. App-based service is a contemporary service that utilizes smartphone technology to facilitate real-time ride pooling, with distinct roles of drivers and passengers [33]. App-based companies extending their services in Dhaka City include Uber, Pathao, Amarbike, Taxiwala, Garivara, Chalo, Sohoj Ride, Obhai, Obon, and others. The service of these companies mainly involves the best possible usage of several modes of transportation, typically comprising cars, bikes, and CNG-powered three-wheeler vehicles. The transportation market is witnessing a rise with the emergence of various app-based transport services [34]. App-based services are gradually becoming prominent in low- and middle-income countries with insufficient public transportation investment [35]. App-based services save a lot of consumer time by instantly sending idle vehicles to customers in need [36]. Motorcycles are one of Dhaka City's predominant modes of transportation for app-based purposes. However, users often avoid them due to their susceptibility to accidents and concerns regarding the safety of women and children. Considering the socio-demographic conditions of people, CNG-powered vehicles have more affordability than cars. The app-based service exhibits the quality of accessibility, interactivity, informativeness, and effectiveness adjusted to the user's particular needs [37]. In the context of an app-based service, passengers are provided convenient access to CNG-powered auto-rickshaws based on their preferences. When the projected arrival time exceeds the user's anticipated timeframe, they can cancel their trip and interact with other available drivers. Before embarking on the journey, individuals can acquire essential details regarding drivers that offer adequate safety. During the trip, passengers can track their whereabouts through GPS and send updates to friends and families. After the trip, ratings can be given to the drivers. The advantages of app-based service include savings in travel costs for the passengers and increased total revenue for drivers, reduced travel time, mitigation of traffic congestion, fuel conservation, and decreased air pollution [38]. Public transit is unsuitable for disabled people, but disabled people take more trips using applications [39]. Unlike private transport, app-based CNGs may not face parking problems. Overall, app-based services can aid public transport effectively. In fact, many researchers stated that consumers have started preferring app-based services over other traditional forms of public transport [40]. The consideration of socioeconomic factors plays a part when selecting an app-based service. In this regard, a CNG-powered auto-rickshaw may be a viable choice for middle- and lower-income individuals. Moreover, app-based CNG auto-rickshaw services provide employment opportunities to a lot of people.

This study aims to analyze the service quality factors of app-based CNG vehicle services that influence the acceptance of the service. Service quality is perceived as an essential determinant of users' travel demand. Over the period, many researchers identified crucial service quality factors of different transportation mediums and transportation infrastructures (i.e., Public buses, railway services, ride-sharing services, sidewalks, and foot-over bridges) [41] –[7]. Better service quality can contribute to the customer

satisfaction [42] [9]. explored that service quality and trust significantly affected customer satisfaction. The service quality of any ride-sharing service is unique and hybrid as it involves not only transportation medium service quality but also the quality attained from mobile app services [10]. Previous studies identified different dimensions while analyzing app-based ride-sharing services' service quality. But in the context of Dhaka City, it is necessary to examine the factors impacting the user's choice of app-based CNG auto-rickshaw facilities. The outcomes of this study will provide a proper scenario of existing Service quality and user's perception towards app-based CNG auto-rickshaw facilities to companies like Pathao, Uber, and Obhai. Overall, this study is expected to guide service providers in developing a sustainable, pollution-free, less congested transportation system.

Methods

The study was carried out using a two-step process. Data from the respondents are gathered in the first step using a questionnaire survey. SEM analysis estimates the proposed hypothesis framework in the second step. For this study, SEM and RII methods are adopted. The process of Structural Equation Model (SEM) estimation is recurrent and ultimately produces the best-fitted model, which supports the hypothesis. Numerous methods, including maximum likelihood (ML), weighted least squares (WLS), and generalized least squares (GLS), can be used to estimate structural equation models. The most widely used of these three approaches is machine learning. The complexity of the SEM, the sample size, the scale properties of the parameters, and various probability distribution assumptions all play a role in choosing the optimal SEM [43]. The model's goodness of fit must be described using multiple steps in order to navigate the complexity of the SEM [44]. Any relationship between variables is not just an empirical association; rather, it is an informal connection. SEM is a highly adaptable technique that can be applied to a wide range of relationships, including direct (A→B), indirect (A→C→B), and interactive (A→C→B and D→C→E). To explain the connections between latent and observed variables, SEM employs path analysis [45]. The term "relative importance index" describes how well a variable predicts a result when used alone or with other variables in combination [46]. When the predictors are interrelated, indices frequently obtained by several regression analyses, the variance is not efficiently partitioned [47]. RII analyses aim to divide explained variation among numerous predictors to understand better each predictor's involvement in a regression equation [48]. In essence, RII describes the contribution of each predictor to the explanation of the variance in the criterion [47]. In some cases, a variable may only account for a very small portion of the predictably observed variance but still be extremely important, and in other cases, it may account for a larger portion of the variance but only have limited practical applicability [49]. Importantly, RII analyses are more effective at showing the true impact of a given predictor than simple correlations or normalized regression coefficients [48].

Data collection and demographics of the respondents

Initially, we carried out a pilot survey of certain variables and reviewed earlier research. Pilot survey identifies particular research topics or questions that require investigation and improvement. A pilot survey is a data collection tool that uses forms for

observations, interview protocols, and questionnaires. Typically, a pilot study's sample size is smaller than the main study's. Finding patterns, trends, or anomalies in the data is made easier with the use of pilot surveys. Additionally, it can shed light on how well the research tools work. Adjust and improve the research instruments, protocols, or other study design elements as needed in light of the feedback and data analysis. The initial opinions of CNG users were gathered for the pilot survey. The complete questionnaire was developed in response to survey feedback. From then on, we gathered information manually and through the online platform. The target respondents were the users of CNG auto-rickshaw in Dhaka City. Online platforms and direct distribution in person were used to gather a total of 157 data. We looked over the data once it was collected. Using the SEM and RII methods, it was also confirmed that the app-based CNG system was accepted. Seventeen Service Quality variables were used in total to create the intended SE model. The remaining 15 variables were observed, while the other 2 were latent variables that were not observed. After conducting extensive literature reviews and focus groups (FGDs) with professionals, scholars, and policy-makers, the variables listed below are discussed. According to a study, fit indices can be taken into consideration for a better hypothesis for more than 150 samples [50]. For assessing acceptance of the app-based CNG auto rickshaw system following steps are shown in Fig. 1.

According to Figs. 2 and 3, Most of the respondents are male, and most of them are in the age range of 20 to 30 years. So, the young generation is mostly using CNG-based automobiles for various purposes.

Independent variables

In total, 15 variables have been used in this study. Variables have been identified from previous studies on CNG auto rickshaw service quality. Variables with their significance are presented in Table 1.

Fifteen variables have been incorporated into two latent variables; "Convenience (η1)" and "Safety and Security (η2)". The variables are demonstrated in Table 2.

Factor analysis

Data reduction is accomplished using factor analysis. Utilizing a minor factor to condense or summarize, a sizable number of variables must be considered [45]. In

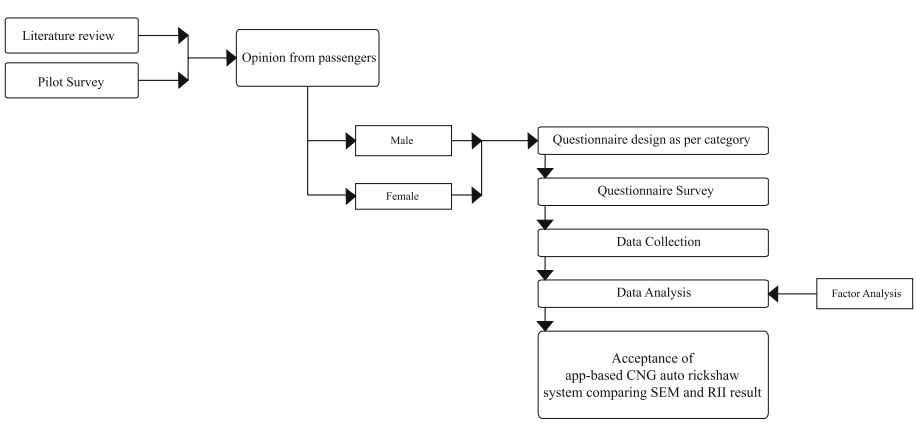

Fig. 1 Flowchart illustrating the process followed to conduct the research

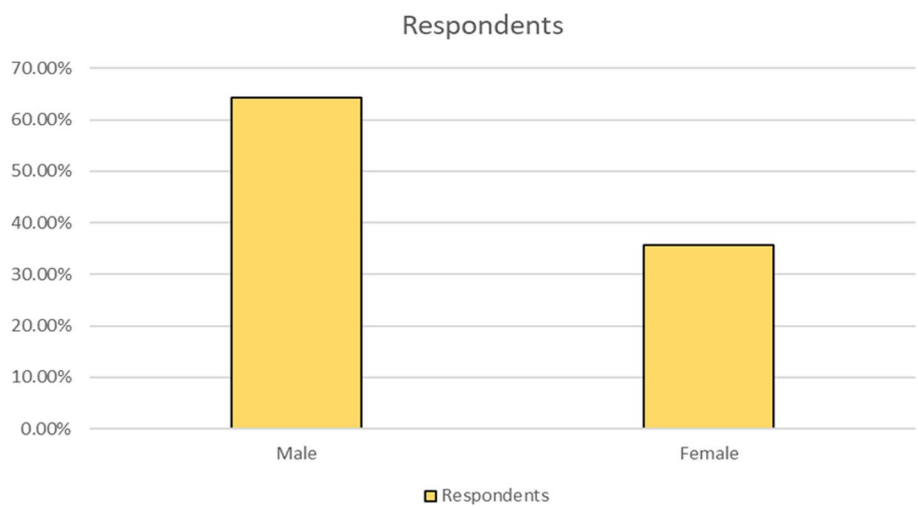

Fig. 2 Gender of respondents

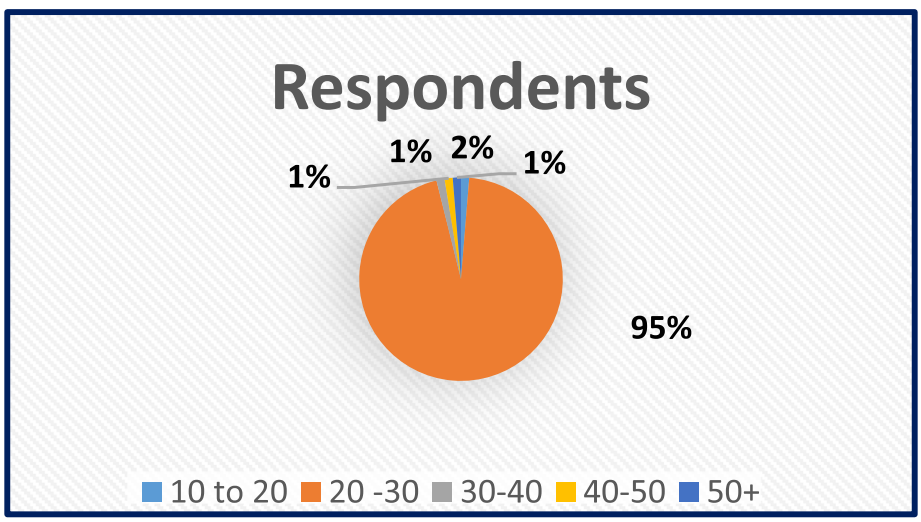

Fig. 3 Age of respondents

this study, the Kaiser-Meyer-Olkin test is used to assess the extent of scale unidimensionality in the collected data (Mathur and Dhulla, 2014). The Kaiser-Meyer-Olkin and Bartlett test was used to determine whether the data were adequate for factor analysis (Napitupulu, Abdel Kadar, and Kartika Jati, 2017). The results of the KMO and Bartlett tests in Table 3 demonstrate that the statistics are suitable for factor analysis.

A further reliability test is conducted by determining the Cronbach's alpha test in Table 4.

The Kaiser-Meyer-Olkin measure of sampling's adequacy score of 0.737 shows that the built model is suitable for factor analysis.

The model demonstrates the relationships between the variables in terms of model fitness. Hooper et al. presented a method for calculating model fit indices Hooper

Table 1 App-based CNG auto-rickshaw variables

Service quality factors of App-based CNG auto-rickshaw service	Description of the variables
Quick mobility	Numerous application-based companies, such as Uber, Pathao, Amarbike, Taxiwala, Garivara, Chalo, Sohoj Ride, Obhai, Obon, and others, have initiated their business operations in Bangladesh. These businesses quickly brought cutting-edge technologies to increase people's mobility, convenience, and flexibility [51].
Profitable	Socioeconomic and demographic factors influence the app-based CNG service choice in Dhaka City [52]. So, a fair fare system for all classes will affect consumers' preferences.
Traditional process	Traditional services differ from app-based Services [53]. In conventional service, people randomly wait and bargain for the fare. Most of the time, there's a chance drivers deceptively collect more money from the passenger.
Availability	The availability of enough vehicles is necessary to earn the trust of app-based users. Even in some cases, car scarcity in peak hours increases the fare. A study's findings indicate that many highly important factors influence consumers' perceptions, including drivers' actions, dependability, image, cost-effectiveness, safety, availability, comfort, and timing [54, 55].
Time affordability	For small-scale ridesharing systems, the addition of meet points to the app-based system reduces the overall travel time by 2.7–3.8% [56].
Cashless payment system	In many countries, online methods like debit cards and credit cards are preferred over cash payment. Moreover, after covid, contactless payment is encouraged [57]. Cash-free services mitigate many risk factors of ride-sharing
Deception	A scenario where fraudulent activities exist within the system, such as fake transactions, unauthorized access and usage, inflated pricing during peak hours, etc., could be referred to as the thread of deception in an app-based CNG system [58].
Better safety	Safety and security are among the seven dimensions identified in perceived app booking quality [35]. Two types of security concerns exist in the operations. Users and drivers must share their personal information, which is critical. Another is the fear of unwanted incidents. Safety and security are the most impactful factors regarding service quality [23].
Safe personal information	Risks include sharing personal details with strangers, like travel itinerary details and schedules [59].
Passenger safety	Introducing mandatory dash cams in the rides can ensure rider safety from the start of the journey until they reach the destination [60].
Convenient online payment	How customers and drivers perceive cashless payment also reflects on accepting this new service. CNG auto-rickshaw facilities share factual time information about waiting times and simplified payment methods [61].
Women's security	According to a women's perception-based study, CNG auto-rickshaw service is advantageous for working women, but safety and security are one of the preliminary concerns [62].
Possibilities of accident	Ref emphasizes the risk of fatigue and sleepiness among ride-sharing drivers, which can lead to drowsy driving accidents [63].
Waiting time	Trip-level characteristics like traffic, the surge multiplier, and inclement weather positively correlate with waiting times [64].
Safety at night	Crimes and harassment are common occurrences at night. Providing passengers with information about their fellow travelers, such as photos, gender, and names, positively affects user experience at night [65]. App-based facilities are safer at night [66].

et al. (2008). Absolute fit indices measure the degree to which a given model fits the sample data. The values of the CFI, NFI, RMSEA, and $\chi 2/\text{df}$ are shown in Table 5.

The fit indices in Table 5 demonstrate the model's excellent fit as well as compliance with all fit requirements.

Table 2 Variables related to app-based CNG auto-rickshaw

Variable name	Variable annotations	Variable type	Numerical scale	Qualitative scale
Quick mobility	y_1	Exogenous	5-1	Strongly disagree to strongly agree
Profitable	y_2	Exogenous	5-1	Strongly disagree to strongly agree
Traditional process	y_3	Exogenous	5-1	Strongly disagree to strongly agree
Availability	y_4	Exogenous	5-1	Strongly disagree to strongly agree
Time affordability	y_5	Exogenous	5-1	Strongly disagree to strongly agree
Waiting time	y_6	Exogenous	5-1	Strongly disagree to strongly agree
Online payment acceptance	y_7	Exogenous	5-1	Strongly disagree to strongly agree
Deception	y_8	Exogenous	5-1	Strongly disagree to strongly agree
Convenient online payment	y_9	Exogenous	5-1	Strongly disagree to strongly agree
Women's security	y_{10}	Exogenous	5-1	Strongly disagree to strongly agree
Better safety	y_{11}	Exogenous	5-1	Strongly disagree to strongly agree
Safe personal info	y_{12}	Exogenous	5-1	Strongly disagree to strongly agree
Safety at night	y_{13}	Exogenous	5-1	Strongly disagree to strongly agree
Passengers Safety	y_{14}	Exogenous	5-1	Strongly disagree to strongly agree
Possibilities of accident	y_{15}	Exogenous	5-1	Strongly disagree to strongly agree

Table 3 KMO and Bartlett's test

Kaiser-Meyer-Olkin measure of sampling adequacy.		0.737
Bartlett's test of sphericity	Approx. chi-square	811.909
	df	136
	Sig.	0.000

Table 4 Cronbach's alpha test

Cronbach's alpha	Cronbach alpha based on the standardized item	No. of item
0.764	0.779	15

Table 5 Fit indices of SE model

Fit indices	SE model	Acceptable limit [44]
Root mean squared error of approximation (RMSEA)	0.072	0.00–0.08
Standardized root mean square residual (SRMR)	0.065	SRMR < 0.10
Comparative Fit Index (CFI)	0.802	Closer to 1.00
Normed Fit Index (NFI)	0.704	Closer to 1.00
X^2/df	2.289	χ2/df < 3.00

Results and discussion

Results of SE model hypothesis testing

The two latent variables "convenience (1)" and "safety and security (2)" are used to introduce the structural model in Fig. 4. Eight exogenous factors are employed to calibrate the "convenience (η1)" latent variable and seven exogenous variables are employed to calibrate the "safety and security (η2)" latent variable. The latent variable "convenience

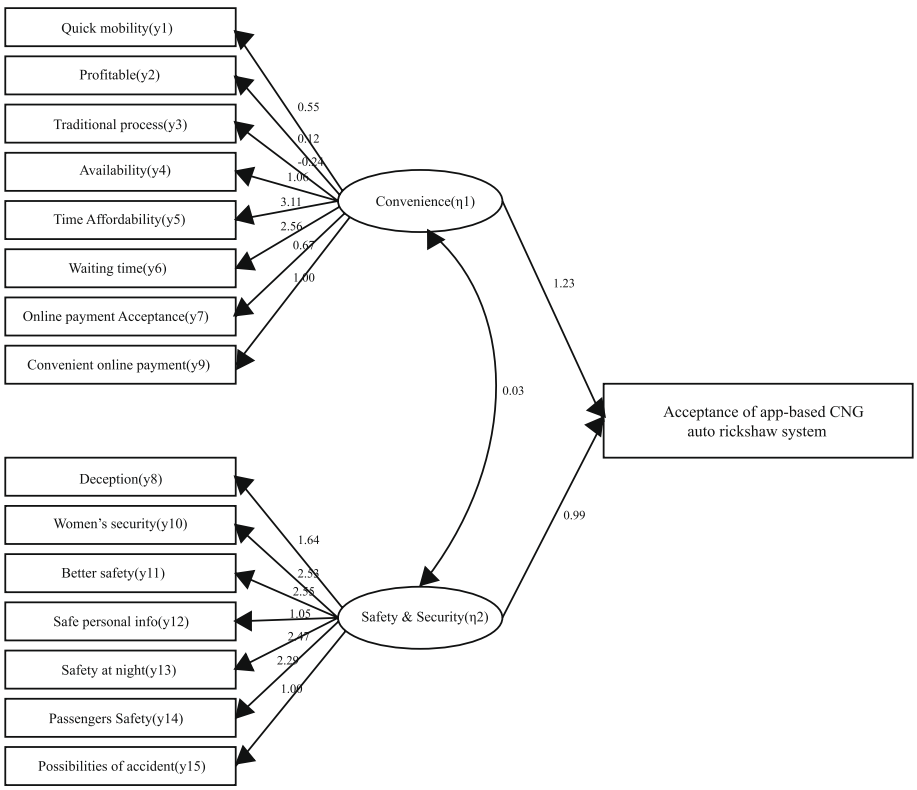

Fig. 4 Path co-efficient outcome of structural equation model

Table 6 The verdicts of the esteemed path's hypothesis testing

Hypothesis statement of path analysis	Path co-efficient	*P* value	Results on hypothesis
H1: Influence of convenience on acceptance of the app-based CNG auto rickshaw service	1.23	***	Supported
H2: Influence of safety and security on acceptance of the app-based CNG auto rickshaw service	0.99	***	Supported
H3: Influence of convenience and safety and security on each other's	0.03	***	Supported

Note: *p<0.05, **p<0.01, ***p<0.001

(η1)" has the highest impact on the acceptance of app-based CNG auto rickshaw service in Dhaka City. The reader would note that the interestingly latent variable "convenience (η1)", and "safety and security(η2)" positively influence each other. Table 6 displays the results of the respected path's hypothesis testing.

From the best-fitted model in Fig. 4, it is identified that the observed variable, i.e., the 'Time affordability (y5)' variable with path co-efficient 3.11, is the most influencing among the eight convenience-related latent variables. The effectiveness and uptake of the app-based CNG service depend heavily on time affordability. For customer convenience, productivity, traffic reduction, cost savings, and environmental benefits, time affordability in app-based CNG services is essential. Additionally, it can give service providers useful information and a competitive advantage. In contrast, 'Traditional process (y3)' is the least significant variable with a path coefficient of 0.12. Long wait times, efficiency

issues, safety issues, and a small geographic service area are among the drawbacks of traditional CNG procedures. App-based CNG services attempt to overcome these shortcomings by providing ease, flexibility, and enhanced user experiences, making them a more appealing choice for many CNG consumers. The best-fitted model also identified that 'Better safety (y11)' is the utmost influential variable through a path co-efficient of 2.55 among the seven observed variables, whereas 'Possibilities of accident (y8)' is the least influence with a path co-efficient of 1.00 from the "safety and security (η2)" latent variable. The acceptance of app-based CNG services depends on their safety. For these services to run smoothly and expand, it is not only morally right to ensure the safety of customers, employees, and the environment, but it is also legally and practically necessary. Accidents in app-based CNG services are undesirable and can have negative effects on operational effectiveness, reputation, and safety. Respondents think that app-based CNG services have fewer chances of accidents.

The output of the SE model is shown in Table 7, and most of the values of the path coefficients are positive. This means that raising a parameter by one unit will have a positive impact on the associated parameter and vice versa [50].

Relative Importance Index

The means and standard deviations of each item, when used to determine the overall rank, are unsatisfactory, according to various research, because they don't take the interactions amid the components into account [69] –[70]. The factors that have been discovered are prioritized and the variables are categorized according to priority using the RII approach [41, 71].

$$\mathrm{RII} = \frac{\sum \mathrm{W}}{\mathrm{AXN}} \tag{1}$$

Table 7 Estimated value of different app-based CNG auto-rickshaw variables

Factor group	Variable notation	*P* value	Path co-efficient value (overall)	Path co-efficient value (men)	Path co-efficient value (women)
Service performance (η1)	y1	***	0.55	1.02	1.23
	y2	***	0.12	0.75	0.95
	y3	***	-0.24	0.63	0.56
	y4	***	1.06	2.35	2.32
	y5	***	3.11	2.08	2.05
	y6	***	2.56	1.63	1.43
	y7	***	0.67	0.94	0.71
	y9	***	1.00	0.88	0.89
Safety and security(η2)	y8	***	1.64	1.20	2.22
	y10	***	2.53	1.17	2.51
	y11	***	2.55	0.91	0.92
	y12	***	1.05	1.87	1.96
	y13	***	2.47	1.14	2.99
	y14	***	2.29	0.83	1.34
	y15	***	1.00	0.56	1.12

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$ [67, 68]

Table 8 Variable Ranking and RII Analysis Results

Factor group	Variable notation	RII value with ranking (overall)	RII value with ranking (men)	RII value with ranking (women)
Service performance (η1)	y1	0.783(2)	0.674(14)	0.622(15)
	y2	0.637(13)	0.698(10)	0.683(12)
	y3	0.622(14)	0.688(11)	0.768(8)
	y4	0.674(11)	0.741(6)	0.852(3)
	y5	0.712(9)	0.872(1)	0.819(5)
	y6	0.650(12)	0.812(3)	0.778(7)
	y7	0.514(15)	0.678(13)	0.689(11)
	y9	0.732(8)	0.671(15)	0.632(14)
Safety and security (η2)	y8	0.775(4)	0.766(4)	0.830(4)
	y10	0.777(3)	0.759(5)	0.869(2)
	y11	0.772(5)	0.723(8)	0.760(10)
	y12	0.681(10)	0.701(9)	0.762(9)
	y13	0.771(6)	0.738(7)	0.899(1)
	y14	0.800(1)	0.835(2)	0.792(6)
	y15	0.741(7)	0.681(12)	0.654(13)

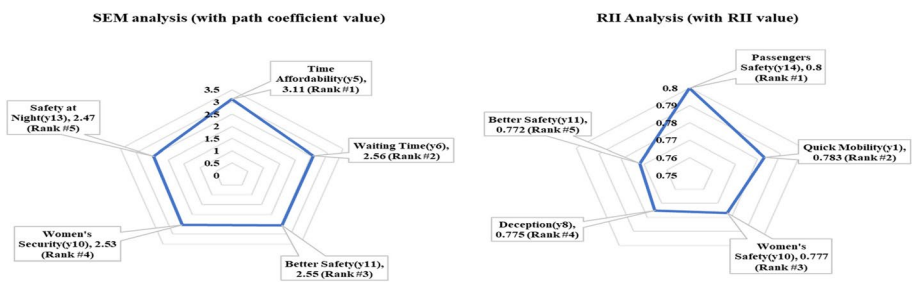

Fig. 5 Utmost five momentous variables that impact the acceptance of app-based CNG auto-rickshaw service according to SEM and RII (radar chart)

Here,

$W =$ Respondents' estimates of each factor's importance

$A =$ Highest weight

$N =$ Sum of all respondents

The range of the RII value is 0 to 1. Carpooling system adoption is most strongly influenced by RII values close to 1 [70, 71]. Table 8 contains the results of the variables' RII analysis.

Comparison between SEM and RII analysis

SEM determines the salient characteristics by connecting the variables. The qualities are identified as the respondents' feedback by RII analysis on the other hand. Rarely do the results of the RII and SEM analyses coincide. However, the service quality of the app-based CNG service is strongly influenced by those matching variables [72].

According to SEM and RII analysis, the 'Women's security (y10)', and "Better safety (y11)" variable is found as the most weighty variable that influences the acceptance of app-based CNG services. The top five significant variables according to SEM and RII are shown in Fig. 5.

Heterogeneity of the study

This study has been conducted using 157 responses. As the target responses are men and women, their perceptions vary from each other's. The respondents' heterogeneity has an impact on the app-based CNG service. The respondents do not perceive every variable in the same way. Respondents are presented as two diverse groups: women and men. It makes sense that the two diverse groups would view the adoption of app-based CNG services differently. As the main analytical technique for heterogeneity analysis, we favored SEM. The data we need is obtained by SEM, which looks into the correlation between the variables after analyzing each stakeholder in heterogeneity separately. To bolster the conclusions even more, we compared the previously mentioned outcomes with RII's analysis. Also, their perception is justified by re-evaluating the SE model. Their variation in perception is shown in Table 9.

Heterogenity-1 (men)

According to men's perception, the service performance of app-based CNG is more concern than safety. To them, this service should be more easily accessible, time affordable, and less waiting charge. According to them, app-based CNG should be available whenever needed in a very short time. During traffic congestion, the waiting charge should be less as comparing the traffic conditions of Dhaka City. Despite this, men also believe that safety is also a concerning issue for them. They perceive that, if their personal information such as; bank account information and mobile banking information gets leaked then there is a possibility of deception. According to men's perception, top 5 variables are shown in Table 10.

Heterogeneity-1 (women)

On the other side, according to women's perception, the safety of app-based CNG is more concern than service performance. Women perceive that, while traveling at night, it's a concern for them. They think their information such as; trip destination, number of passengers, and payment method are disclosed then there arises a safety concern. Women also have concerns about convenient online payment systems.

Table 9 Perception variation towards app-based CNG variables by various respondents (with path co-efficient value)

Category of respondents	Service performance (η1)	Safety and security (η2)
All respondents	1.23	0.99
Men	1.34	0.81
Women	1.03	1.86

Table 10 Most significant variables according to men's perceptions

SEM analysis	
Variables with path co-efficient	Factor group
Rank #1: Availability (y4), 2.35	Service performance (η1)
Rank #2: Time Affordability (y5), 2.08	Service performance (η1)
Rank #3: Safe personal info (y12), 1.87	Safety and security (η2)
Rank #4: Waiting time (y6), 1.63	Service performance (η1)
Rank #5: Deception (y8), 1.20	Safety and security (η2)
RII analysis	
Variables with RII value	Factor group
Rank #1: Time Affordability (y5), 0.872	Service performance (η1)
Rank #2: Passenger safety (y14), 0.835	Safety and security (η2)
Rank #3: Waiting time (y6), 0.812	Service performance (η1)
Rank #4: Deception (y8), 0.766	Safety and security (η2)
Rank #5: Women safety (y10), 0.759	Safety and security (η2)

Table 11 Most significant variables according to women's perceptions

SEM analysis	
Variables with path co-efficient	Factor group
Rank #1: Women's security (y10), 0.73	Safety and security (η2)
Rank #2: Safety at night (y13), 0.69	Safety and security (η2)
Rank #3: Safe personal info (y12), 0.65	Safety and security (η2)
Rank #4: Waiting time (y6), 0.62	Service performance (η1)
Rank #5: Convenient online payment (y9), 0.56	Service performance (η1)
RII analysis	
Variables with RII value	Factor group
Rank #1: Safety at night (y13), 0.899	Safety and security (η2)
Rank #2: Women's security (y10), 0.869	Safety and security (η2)
Rank #3: Availability (y4), 0.852	Service performance (η1)
Rank #4: Deception (y8), 0.830	Safety and security (η2)
Rank #5: Time affordability (y5), 0.819	Service performance (η1)

Without a convenient payment system, there arise safety issues. According to women's perception, the top 5 variables are shown in Table 11.

Conclusions

There are many different modes of transportation available in Bangladesh's public transportation system, from more conventional choices like CNG auto-rickshaws and ride-sharing services to more conventional ones like buses, rickshaws, and boats. Due to government incentives and concerns about the environment, CNG is now more widely used in Bangladesh as a cleaner and more environmentally responsible substitute for petrol and diesel. This study examines the acceptance and perceptions of app-based CNG auto rickshaw service in Dhaka City.

The developed structure equation model suggests that convenience in app-based CNG auto rickshaw service is preferable in terms of safety issues. App-based CNG auto rickshaw services are designed to offer a range of conveniences to users, such as simplifying

the refueling process, saving time, and providing additional features that enhance the overall user experience.

Among the fifteen observed variables, women's security (y10), and better safety (y11) are the most significant ones. It is crucial to prioritize women's security in app-based CNG services. For this service to succeed and endure, it is essential to ensure the safety and well-being of female passengers. Maintaining women's safety in CNG services encourages gender equality and makes sure that women have unrestricted access to transportation services. This covers defense against abuse, violence, theft, and other types of harm. If women feel unsafe, they may choose not to use CNG services, which can result in a significant loss of potential economic output. The use of these services may increase if their security is ensured. To ensure women's safety in transport services, governments and regulatory bodies may impose legal requirements. The provision of such services requires that these obligations be fulfilled.

To make CNG auto rickshaws more acceptable to women and others, the government should verify the credibility of drivers by conducting in-depth background checks on them. For the purpose of thoroughly investigating those requesting CNG driver's licenses, the government may work with law enforcement organizations and other private sector authorities. Verifying the authenticity of identity documents and looking up driving and criminal histories are all included in this. CNG drivers can receive standardized training and certification through programs established by the public sector in partnership with government agencies. In terms of safety procedures, traffic laws, and customer service, this guarantees that drivers are properly taught. The credibility of CNG drivers can be improved by putting digital identity verification systems in place. Driver identity verification could be verified through biometric verification, facial recognition software, or other safe techniques. Work together to incorporate data about CNG drivers into national databases. This may involve exchanging information in real-time about the status of driver's licenses and background checks with law enforcement. Create a system wherein CNG drivers and vehicles are regularly inspected and audited. A combined task force made up of public sector representatives and government officials can handle this. Inspections may concentrate on driver compliance, emissions regulations, and vehicle safety. Provide safe and private data-sharing channels that facilitate easy communication between public sector organizations and government agencies. This guarantees that individuals in charge of monitoring and enforcement can access pertinent data regarding CNG drivers. Drivers should receive instructions on how to respect the space between them and their passengers. Offer receptive and trustworthy customer support to help passengers and drivers in case of issues or emergencies, and enforce strict policies against harassment and misconduct with clear consequences for offenders.

App-based CNG service providers can put in place a number of measures to improve safety, including vehicle inspections, real-time tracking, safety education, and training. The success and expansion of the service are ultimately impacted by their ability to produce a safer and more desirable transportation option for both drivers and passengers.

Despite these intriguing results, this study does have some drawbacks. The sample size is low. Although we use the normal distribution to sample the respondents, the SEM's accuracy will be increased by more exact sampling that makes use of census tract data. Further study can be performed using hard data.

Abbreviations

CNG	Compressed natural gas
ML	Maximum likelihood
NFI	Normal Fit Index
RII	Relative Importance Index
RMSEA	Root mean squared error of approximation
SEM	Structural equation modeling
SE	Structural equation
SPSS	Statistical Package for Social Sciences
WLS	Weighted least squares

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Authors' contributions
TJ and MS prepared the questionnaire, collected data, and analyzed the data. MM has also contributed to conceptualization, data collection, writing, and conceptualization. SA has also contributed to its data collection, writing, and reviewing. SM contributed by providing valuable feedback, revising the manuscript, and approving the final version for submission. All authors read and approved the final manuscript.

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Declarations

Ethics approval and consent to participate
I certify that the authors alone have written this work and that no previous application for a degree has ever included it, in whole or in part.

Competing interests
The authors declare that they have no competing interests.

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