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Promoting social sustainability: Psychological and contextual factors influencing mobility scooter adoption among older adults in a developing country

Ala Kordrostami [a], Javad Esmailpour [b], Kayvan Aghabayk [a,*], Nirajan Shiwakoti [c]

[a] School of Civil Engineering, College of Engineering, University of Tehran, Tehran, Iran
[b] Department of Civil Engineering, Schulich School of Engineering, University of Calgary, Calgary, Alberta, Canada
[c] School of Engineering, RMIT University, Melbourne, Australia

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ABSTRACT

Equitable transportation for minority groups, such as older generations, is fundamental to social sustainability, as active participation in society improves their quality of life. Mobility scooters have the potential to promote independence among older adults so that they can participate in society alongside reducing dependency on motor vehicles, contributing to more sustainable urban mobility solutions. However, in developing countries, existing literature reveals a gap in quantitively assessing and comparing different factors influencing their adoption, especially psychological factors, such as external shame. This study examines mobility scooter acceptance among the elderly (aged 60+), in Tehran, a large metropolitan area, and Gorgan, a small city in Iran. An extended Technology Acceptance Model (TAM) with seven constructs, including the novel introduction of "Shame," was assessed using data from 805 respondents through face-to-face interviews. The second part of the study measured observed heterogeneity using multi-group analysis (MGA) to examine the effects of two moderators: city size and daily physical challenges. The results highlight “Shame” as a predictor of mobility scooter acceptance, with different impacts between the two cities. In the small city, “Shame” negatively moderates other constructs, while in the large city, perceived usefulness is a more decisive predictor; suggesting that practicality holds greater sway in such contexts. These results highlight the importance of psychological factors, especially "Shame," in predicting mobility scooter acceptance based on city size. In light of these findings, tailored policies and strategies are proposed to address the unique psychological and contextual barriers faced by older adults in small and large cities, advancing social equity in sustainable transportation for the elderly.

1. Introduction

With the global population of people above 65 forecasted to grow to 1.5 billion by 2050 [1], proactive measures are needed to address transportation challenges for this group to promote independence and social inclusion. Social inclusion is not only a significant notion in social equity, but also an important goal of sustainable developments [2,3]. Thus, achieving social sustainability, often an overlooked component of sustainability, through age-friendly and equitable transport systems is essential.

Moreover, limited mobility among older adults can result in negative health outcomes, such as social isolation, depression, and reduced physical activity [4–8]. Aging is frequently associated with mobility impairments [9,10], leading to difficulties in outdoor travels for older people [11,12], and a reduced likelihood of making daily trips. To address this, sustainable mobility solutions, such as mobility scooters, are gaining attention for their potential to improve quality of life [3,9] and reduce environmental impact.

1.1. A solution for older citizens: mobility scooters

While mobility scooters emerged several decades ago, they have only recently gained significant popularity. Today, they are seen as an alternative mode of transportation for older adults, offering a convenient substitute for walking without the challenge of driving motor vehicles. They enhance the mobility of individuals facing challenges in

* Corresponding author.
E-mail addresses: Akordrostami@ut.ac.ir (A. Kordrostami), javad.esmailpour@ucalgary.ca (J. Esmailpour), kayvan.aghabayk@ut.ac.ir (K. Aghabayk), nirajan.shiwakoti@rmit.edu.au (N. Shiwakoti).

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walking, precisely those who have the ability to walk but need assistance for specific travels, such as in malls or for outdoor mobility. Most walking trips of older adults are of short distances [2]. As mobility scooters are designed for short-distance trips, they can significantly be of use for this group. Additionally, mobility scooters are electrically powered vehicles, which is a key factor contributing to environmental sustainability by reducing fuel consumption and pollutant emissions.

User-friendly controls and compact designs of these scooters empower individuals to pursue daily life with greater ease and independence. These scooters can compensate for mobility limitations without requiring special training [13], enhancing users' participation, role maintenance, freedom and social interaction [9]. Despite these benefits, the challenges of the adoption and deployment of mobility scooters have been largely overlooked as they have not been analyzed quantitatively to the same extent as other technology-driven strategies [14].

So far, limited studies from countries like the UK, Canada, Australia, and Israel consistently show that mobility scooters improve users' overall wellbeing [15–18]. However, older adults' willingness to use mobility scooters varies in different areas. For example, in Israel, infrastructure issues and the convenience of personal cars reduce the usage of mobility scooters [17], while Australians appreciate the feeling of independence scooters provide [16]. That being said, the acceptance of mobility scooters has not yet been studied using Technology Acceptance Models (TAM), commonly applied to other transport technologies like autonomous vehicles and e-scooters [19–23]. Further, their acceptance in developing countries, that face distinct challenges different from developed nations like the US, especially in case of psychological factors [24], population and air pollution [25] remains largely unexplored.

1.2. Perceptions in large and small cities

With the population of individuals over 60 in Iran projected to reach 24 million [26], about 25 % of the total population by 2050, addressing the mobility needs of older adults has become increasingly important. Additionally, in developing countries like Iran, research on travel patterns among older individuals is predominantly focused on large cities, with limited insights into smaller cities [5,6,27].

According to previous studies, an understanding of social attitudes should be built to evaluate the potential of introducing innovations such as smart vehicles in different urban settings [28]. As social attitudes differ in small cities and metropolitan areas, gaining new insights into individuals' perspectives on technologies, such as mobility scooters, is important [29]. Considering the differences in technology acceptance and influencing factors between large and small cities, different outcomes with different policies seem inevitable.

1.3. The stigma of "Shame"

Social influence has significantly affected elderly attitudes toward transportation [3], impacting both positive and negative views [30]. Older individuals often show less interest in new technologies [19], which could be due to external shame. Shame, a prominent cultural component heightened in later life by changes in physical and health status, explains the reluctance of older adults to adopt new technologies, further intensified by the stigma regarding using such assistive devices.

Technologies specifically designed for older individuals may be perceived as symbols of frailty, raising concerns about being judged as dependent or incapable [30]. Jang (2019) [31] highlights the liminality of mobility scooter users, occupying an ambiguous social and physical space – neither fully ambulatory nor fully dependent on wheelchairs. This creates a dual challenge: infrastructural barriers, such as inaccessible sidewalks and poor public transit design, hinder mobility, while social barriers, including stigma, judgment, and assumptions about their cognitive or physical abilities, discourage adopting these devices despite their potential benefits.

Disability studies highlight invisibility and hypervisibility, further illuminating the social dynamics of mobility scooter use [31,32]. Invisibility refers to overlooking or ignoring scooter users in public spaces, leading to neglecting their needs. Conversely, hypervisibility involves heightened attention and judgment faced by scooter users, marking them as "deviant" or "other." Jang (2019) [31] emphasizes that this tension between invisibility and hypervisibility stems from the imposed liminality where scooter users may be ignored when they need assistance (invisibility) or face intrusive questions and judgments about their need for the device (hypervisibility). This lack of clear societal norms reinforces stigma and shame and deters mobility scooter adoption.

In addition, Leeming & Boyle (2013) [33] argue that shame arises when individuals see themselves through the lens of societal judgment. A study in Canada found that despite recognizing the role of mobility scooters in enhancing quality of life and social inclusion, their association with aging and disability often causes internalized stigma [32].

Finally, some studies assert that social influence, particularly from family and friends, amplifies feelings of shame [34]. In a semi-structured interview with older preclinically disabled participants in Greater London, individuals who did not use mobility scooters held negative perceptions about the idea of needing one, since they viewed it as a verification of their loss of mobility and felt ashamed about it [35]. Through the study of mobility scooters among the older members of society in New Zealand, [36] highlighted that an individual-based perspective on disability, often associated with the medical model, focuses on personal impairments rather than societal barriers. This perspective is particularly reinforced in small cities where strong family ties and dense social networks shape daily life. In these settings, older adults are more socially embedded, and their choices are highly visible to their community. Thus, concerns about being perceived as frail or dependent are intensified, leading to heightened feelings of external shame. The sense of shame can be even more pronounced in developing countries, where using alternative transportation to private cars, which are symbols of social status, is often viewed negatively, and opting for other modes may be seen as a loss of status within one's social circle [37].

As outlined, cultural context plays a crucial role in shaping external shame among the aging population, as they become increasingly aware of how others perceive their physical limitations. Collectivist societies, such as Iran, report higher levels of external shame than individualistic cultures, as communal perceptions are more emphasized due to social norms [38]. In smaller cities, with stronger community ties, older adults fear being labeled as disabled if they use mobility scooters. On the other hand, urbanization, the increasing number of immigrants and diverse social and cultural backgrounds may be reducing the impact of social norms and shame in larger cities. This study, therefore, incorporates external shame into the TAM framework to examine its role in mobility scooter acceptance across different urban settings.

1.4. Contributions

This research makes several key contributions:

1) It pioneers the use of technology acceptance models to quantitatively assess the adoption of mobility scooters among older adults, extending the TAM framework by incorporating additional factors.
2) It addresses a research gap by comparing the acceptance of mobility scooters amongst elderly citizens in large and small cities using SEM-MGA, highlighting how different living conditions influence acceptance and providing insights to guide policies for diverse areas.
3) It introduces "Shame" as a novel factor in mobility scooter acceptance among the older population, enriching technology acceptance models. By validating shame as a determinant, it

uniquely contributes to understanding adoption behaviors in a culturally relevant context.

The abbreviations used in the following parts of this paper are provided in Table 1.

2. Research background and hypotheses

2.1. Technology acceptance models

The original Technology Acceptance Model (TAM) proposed by Davis (1985) [39] posited that Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) are the primary determinants of Attitude (ATT), which in turn influences actual system use. Unlike Fishbein and Ajzen's Theory of Reasoned Action (1977) [40], which emphasizes Behavioral Intention (BI) as a crucial intermediary step, the initial TAM did not include BI as a distinct construct, as Davis (1985) [39] argued that intention may not always form naturally but is artificially induced by research settings.

PEOU influences ATT both directly and indirectly through PU, meaning that if a technology is perceived as easy to use, individuals are more likely to form a positive attitude toward it, even before considering its practical benefits. Later adaptations of TAM incorporated BI to better capture the cognitive processes behind technology adoption [41]. In this study, we employ an extended TAM framework that includes BI alongside additional constructs relevant to mobility scooter adoption.

Building upon TAM, [42] proposed the "Theory of Planned Behavior" (TPB), adding the concept of [39] "Subjective Norms" (SN), measuring the influence of perceived social pressure on technology use.

Later, [43] expanded the models with the "Unified Theory of Acceptance and Use of Technology" (UTAUT), incorporating "Performance Expectancy" (PE), "Effort Expectancy" (EE), and "Social Influence" (SI), which correspond to PU, PEOU and SN, respectively. UTAUT, also involved moderators, including gender, age, experience, and voluntariness of use.

UTAUT2, as [44] extended, introduced three new components: "Hedonic Motivation" (HM), "Price Value" (PV), and "Habit" (H). These, along with PE, EE, and SI affect use behavior through BI. In fact, UTAUT2 was built upon the UTAUT framework, where age, gender, and experience were used as moderators.

In addition to the discussed factors, UTAUT and UTAUT2 introduce "Facilitating Conditions" (FC), including infrastructural, financial, and technical support enabling the adoption of a technology. In the context of mobility scooters, FC could include designated path availability, subsidies for scooter purchase, and maintenance services. While our study primarily examines psychological and social factors influencing adoption, we acknowledge that FC may play a crucial role, particularly in urban environments where accessibility barriers are more pronounced.

Table 1
List of abbreviations.

TAM	"Technology Acceptance Model"
UTAUT	"The Unified Theory of Acceptance and Use of Technology"
UTAUT2	"The Unified Theory of Acceptance and Use of Technology 2″
SEM	"Structural Equation Model"
PCA	"Principal Components Analysis"
EFA	"Exploratory Factor Analysis"
CFA	"Confirmatory Factor Analysis"
MGA	"Multi-Group Analysis"
ATT	"Attitude"
BI	"Behavioral Intention"
PU	"Perceived Usefulness"
PEOU	"Perceived Ease Of Use"
HM	"Hedonic Motivation"
SN	"Subjective Norms"
S	"Shame"

Many researchers in transportation have used or expanded on these models. [45] studied electric vehicle adaptation using UTAUT2, while Rejali et al. (2021) extended TAM to assess e-scooters acceptance in Iran, incorporating SN and HM [46]. Also, regarding the elderlies' transportation, Motamedi et al. (2021) used an extended TAM to evaluate older adult drivers' opinions on car automation levels [47].

Although mobility scooters are a well-established technology, understanding their acceptance among older adults requires examining psychological and contextual factors that drive prior acceptance – factors overlooked by traditional models. Previous studies have used a variety of methods. Research in Australia relied on descriptive statistics and cross-tabulation analysis to understand usage patterns [16], identifying practical benefits like independence and safety concerns as key factors. Studies in Israel conducted opinion surveys through face-to-face interviews coupled with field observations and binary logistic regression models to analyze actual scooter-user behavior [17], highlighting infrastructure barriers. In contrast, studies in Canada and the UK have predominantly employed qualitative approaches [9,15,18], emphasizing emotional benefits such reduced isolation and environmental challenges. These methodologies are designed to capture real-world experience or in-depth opinions post-adoption. In our study, however, a priori acceptance of mobility scooters is the main focus– what older adults perceive before widespread use occurs in Iran. By extending the Technology Acceptance Model (TAM) to include constructs such as "Shame," our framework specifically addresses the cognitive and emotional factors that may influence initial acceptance. This theoretical approach is more suitable for our research objectives, providing a robust foundation to examine the underlying determinants of prior acceptance rather than post-adoption behaviors.

Our study builds upon the Technology Acceptance Model (TAM), incorporating its core constructs – "Perceived Usefulness" (PU), "Perceived Ease of Use" (PEOU), and "Attitude" (ATT) – while also including "Behavioral Intention" (BI), which was introduced in later extensions of TAM [41,48]. Additionally, we integrate "Subjective Norms" (SN) and "Hedonic Motivation" (HM), which have been identified as significant determinants in transportation-related technology adoption studies [46]. These factors originate from research utilizing the UTAUT2 framework but are incorporated here in an extended TAM rather than a hybrid TAM-UTAUT2. This follows previous studies, such as [46], which selectively integrated UTAUT-derived factors into TAM to better capture specific mobility adoption behaviors. Our focus is on psychological and social influences rather than infrastructural or habitual factors. Thus, elements such as "Price Value", "Habit", and "Facilitating Conditions" were not included. By doing so, we maintain the TAM structure while extending it to include factors most relevant to mobility scooter adoption among older adults. Notably, a novel construct named "Shame" (S) was introduced to investigate how older people's perception of using mobility scooters as an embarrassing act affects their intention to use them.

2.2. Research hypotheses

The following subsections present the hypothesis developed for this study.

2.2.1. Relationships between "Perceived usefulness", "Perceived ease of use", "Attitude", and "Behavioral intention"

Previous studies have shown significant relationships between the four original components of TAM. "Attitude" (ATT), as the overall sense of using technology, is the most important predictor of "Behavioral Intention" (BI). On the other hand, "Perceived Usefulness" (PU) and "Perceived Ease Of Use" (PEOU), as the most important constructs of TAM, have direct and indirect effects on ATT and BI, respectively. Hence, five research hypotheses are assumed:

H1: "Attitude positively and directly affects Behavioral Intention"

H2: "Perceived Usefulness positively and directly affects Behavioral Intention"
H3: "Perceived Usefulness positively and directly affects Attitude"
H4: "Perceived Ease Of Use positively and directly affects Attitude"
H5: "Perceived Ease Of Use positively and directly affects Perceived Usefulness"

2.2.2. Impacts of "Hedonic motivation" on other components

In addition to the four original factors of TAM, "Hedonic Motivation" (HM) has been found to be significant in previous research on the acceptance of both e-scooters and electric vehicles [45,49]. HM is an important feature in predicting technology usage, which is the extent to which users would find a device or technology enjoyable to use. As the focus group of this study is the older citizens, the role of hedonic motivation may be even more significant. If older adults find using a device fun and pleasant, they tend to have a more optimistic sense of it. Thus, the effect of HM on ATT is hypothesized as:

H6: "Hedonic Motivation has a positive and direct effect on Attitude".

2.2.3. Relationships between "Shame" and other components

"Shame" (S) can stem from feedback or criticism of others. Among older adults, due to physical changes and health issues associated with aging, it can be even more significant. The older people are more likely to experience shame about using a new device when they receive negative feedback from family, friends, and others in their social circle, especially as aging is generally associated with losing independence and physical abilities and the perception of not being capable of learning new technologies [2]. Based on this, the next hypothesis is proposed as:

H7: "Subjective Norms has a negative and direct effect on Shame"

Additionally, "Shame" (S) can affect all other adoption determinants of the model directly or indirectly. Shame negatively affects PU. Individuals ashamed of using mobility scooters may dismiss their benefits, because they see them as symbols of decline. This reluctance leads to a cognitive bias – older adults downplay the usefulness of mobility scooters, even when they recognize their functional advantages. This aligns with studies on stigma and assistive technologies, suggesting that external judgment undermines users' perceived utility of mobility aids [30].

Second, Shame is expected to negatively impact PEOU. When older adults experience external shame, they may avoid learning how to use a mobility scooter, fearing judgment or social rejection. Negative emotional states can reduce confidence in learning new technologies, and reinforce avoidance behaviors [38].

Finally, Shame significantly influences BI, as emotions play a crucial role in shaping intentions toward technology [43]. If older adults associate mobility scooters with dependency or social stigma, they are less likely to use them. So, the next hypotheses of this research are expressed as:

H8: "Shame negatively and directly affects Hedonic Motivation"
H9: "Shame negatively and directly affects Perceived Usefulness"
H10: "Shame negatively and directly affects Perceived Ease Of Use"
H11: "Shame negatively and directly affects Behavioral Intention"

2.2.4. Effects of living in a small or large city on the conceptual model

Novelties, such as smart vehicles, digitalization, and alternative fuel systems require consideration of social attitudes [28]. The same case is true for mobility scooters. Thus, the role of social norms and shame must be differentiated between two city sizes. In smaller cities, where proximity to family and friends intensifies social influence on older people [34], there is a heightened susceptibility to negative peer feedback regarding using mobility scooters. This increased social pressure may exacerbate shame associated with scooter use, potentially reducing the perceived usefulness of mobility scooters in older persons' daily routines. Based on this, the next research hypothesis is proposed as follows:

H12: Living in a small city negatively moderates the effect of "Shame" on "Perceived Usefulness"

For the older people who live in a large city, the most important factor for predicting using mobility scooters would be practicality rather than subjective norms or shame. Since, in large cities, people typically are not close to their family or friends, the role of subjective norms and shame does not seem to be that important. However, if older citizens find mobility scooters practical, they show a more optimistic attitude towards using them. Therefore, the next research hypothesis is assumed as:

H13: Living in a large city positively moderates the effect of "Perceived Usefulness" on "Attitude"

The proposed model and hypotheses are shown in Fig. 1.

3. Case study, sample, and survey design

In this research, aligning with prior findings on technology acceptance of older citizens, people aged above 60 years old were targeted [5,50–53]. Two cities, Tehran, the bustling capital with over 8.7 million residents [26], and Gorgan, a smaller northern city with about 360,000 residents [26], were selected to represent larger and smaller urban settings in Iran. These two cities were assumed to represent all the other large and small cities in the country. Tehran is characterized by a complex transportation network with extensive metro, BRT, and bus services, yet many older residents still face significant accessibility challenges. The public transport system struggles to meet rising demand, leading to congestion, overcrowding, and long wait times. This compels many residents to rely on private cars, worsening traffic and pollution [54]. In contrast, Gorgan relies on taxis, and limited bus services due to its underdeveloped transit system. These differences provide an essential contextual backdrop for our study, helping to explain the different perceptions and adoption patterns observed in these urban environments.

In the first step, the common places in two cities where older adults usually gather were identified in different municipality districts of the two cities, including rehabilitation centers, hospitals and outpatient clinics, as well as local parks, and local shops. This selection strategy ensured a diverse sample from a range of socio-economic backgrounds and different levels of mobility difficulties. Additionally, demographic characteristics such as gender, income level, educational level, and self-reported health status were recorded and compared across both cities to assess the diversity (Table A1). While national-level data on mobility difficulties were unavailable, our questionnaire captured varying mobility levels, from mild to severe mobility difficulties. Notably, potential mobility scooter users are not those entirely unable to walk but those who can walk with difficulty. Therefore, our sample was intentionally designed to capture this group.

The data was gathered through in-person interviews conducted in the field during February and March 2023 in both cities. The places in different municipality areas were chosen at random and older adults also were randomly invited to the interview. In order to participate in our study, participants must have two criteria: (i) willingness and (ii) to be aged 60 and above, and the exclusion criterion was reluctance to participate.

To conduct the interviews, the study and its objectives were explained verbally to the participants. To ensure they had a basic understanding of mobility scooters, a short, neutral video clip was shown prior to the interviews. The video was purely informational, deliberately avoiding persuasive language or value judgments to minimize potential

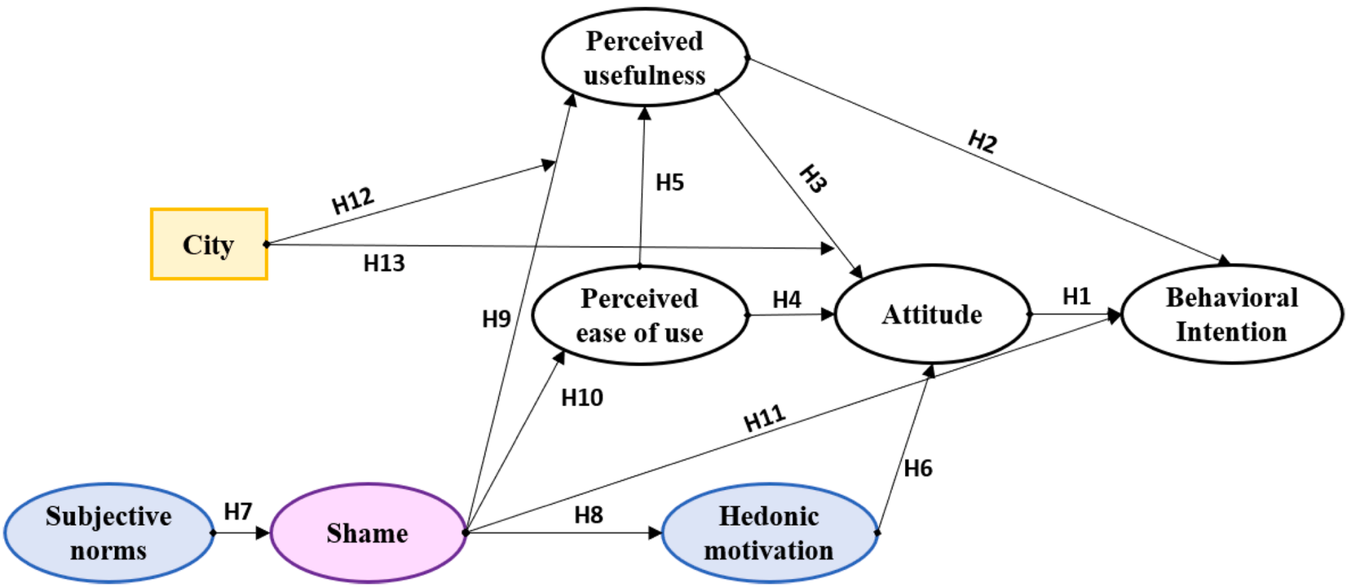

Fig. 1. Conceptual model and Hypotheses.

priming effects. This step was necessary given the limited public exposure to mobility scooters in Iran. Each interview took 20–30 min, and in the end, the participants were thanked kindly. Overall, 805 valid questionnaires were collected, 406 in Gorgan, and 399 in Tehran.

To minimize potential interviewer and social desirability bias, we followed several best practices by Podsakoff et al. [55]. Interviewers were trained to maintain a neutral tone and to present questions clearly and concisely without leading language. Additionally, given the literacy levels of older adults in Iran, computer- and paper-based self--administered surveys were not feasible. Home-based surveys were also impractical, as many participants lacked the technological skills required to view the introductory video. Finally, to further reduce bias, participants were assured of anonymity and the absence of right or wrong answers, reducing evaluation apprehension. Interviews took place in low-pressure atmospheres, encouraging open and authentic responses.

The questionnaire contained two sections. The first part covered socio-demographics, travel habits, and health conditions (Table A1) for both cities to ensure that the samples had similar characteristics. The latter part of the questionnaire (Table A2) covered latent constructs, using a five-point Likert scale (0=extremely disagree to 4=extremely agree). All indicator variables except for those of construct "Shame" were extracted from previous studies on TAM, UTAUT, UTAUT2, and extended TAM [19,20,39,42,43,46,49,56,57]. The construct "Shame" emerged from qualitative research that was done prior to the questionnaire design, including interviews with 32 older citizens and open-ended questions that highlighted their embarrassment about using mobility scooters. In these pilot study interviews, the respondents were requested to elaborate on the reasons for their intentions to use mobility scooters or their reluctance to utilize them. Their answers to this question were transcribed and read through carefully. After analyzing the answers, the most common factor mentioned by the respondents was feeling ashamed of using mobility scooters in public, as they supposed that mobility scooters are a symbol of aging and incapacity. Based on the results of this pilot study, three indicator variables were defined and put in the questionnaire to measure the feeling of shame: "I feel ashamed of using mobility scooters among people.", "In my opinion, people who use mobility scooters are very old.", "In my opinion, if I use mobility scooters people think that I am very old."

4. Methodology

4.1. Structural equation modelling

The process of estimating a SEM consisted of different steps: (i) PCA to identify the general patterns of indicator variables and their constructs, (ii) EFA to extract the latent variables, (iii) CFA to validate the well-measured constructs, (iv) and finally estimating the SEM.

PCA was used to assess the factorial structures of variables and how variables and latent constructs were related, using the "Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity". A KMO above 0.6, and significant Bartlett's Test ($p < 0.05$) are acceptable. Ideal factor loadings would be higher than 0.7, though that of over 0.5 are acceptable [58]. Then, a measurement model was run that related all indicators to their respective components as identified by PCA. A well-fitting measurement model ensured convergent validity, meaning all indicators align well with their construct [59]. Construct validity and Goodness-of-fit (GOF) were assessed to ensure that constructs were well-measured for the conceptual model. The "Root Mean Square Error of Approximation" (RMSEA) and "Comparative Fit Index" (CFI) are stated as recommended by Hair et al. [58]. Although it is not recommended to use an absolute cut-off value for RMSEA [60], MacCallum et al. (1996) assert that RMSEA values lower than 0.08 show a good fit, with values lower than 0.05 showing a very close fit [61]. Many studies have used an RMSEA value lower than 0.08 to control the model fit [58,59,62,63]. For CFI, values higher than 0.9 indicate a good model fit [61].

Construct validity was measured through convergent validity and discriminant validity [64]. Factor loading above 0.7, "Average Variance Explained" (AVE) above 0.5, and satisfactory reliability of the constructs show good convergent validity. Constructs' reliability is determined by using "composite reliability" (CR) and "Cronbach's alpha". Reliability values above 0.7 indicate that there is good internal consistency in each construct [65]. Reliability between 0.6 and 0.7 might be acceptable, if other indicators of a model's construct validity are good [58]. Finally, discriminant validity is confirmed when the AVE for each construct is more than the squared correlation between any two constructs [58].

After confirming the measurement model's fit, a structural model using IBM SPSS AMOS 24 software was conducted to evaluate research hypotheses. To achieve this purpose, structural relationships between the proposed constructs were formed according to the conceptual model. The practical significance of structural relationships through standardized structural coefficients were evaluated; values below 0.1 represent a very weak relationship, 0.1–0.3 represent a weak relationship, 0.3–0.5 represent a moderate relationship, and values above 0.5 represent a strong relationship between constructs [62,66,67].

Before analysing the data using SEM, data points were checked for potential missing values and outliers, which were removed from the dataset. Regarding multicollinearity, in SEM, a moderate correlation between observed variables is necessary to form the constructs. However, extremely high correlations (>0.85) should be avoided. Additionally, normality is relaxed in cases of high sample size, as the sampling distribution of the estimated parameters in SEM becomes approximately normal regardless of the distribution of the data.

To provide a clear overview of the research methodology, Fig. 2 presents a flowchart that outlines the key stages of the data collection and analysis process.

4.2. MGA

MGA was used to investigate the effects of moderators on relationships among latent variables. MGA also allows to fit the model to different moderators simultaneously. Proper moderator selection requires testing "measurement invariance" (MI) and "structural invariance" (SI). MI tests whether the measurement model remains consistent across groups by imposing increasingly strict equality constraints, typically worsening the fit indices. The change in "Comparative Fit Index" (ΔCFI) exceeding 0.01 between two consecutive MI models indicates that MI is not held, making the variable suitable for inclusion in SEM-MGA [68–70].

To test measurement invariance, four types of MIs were assessed [71]:

1. Configural invariance: Ensures the number of constructs and the pattern of relationships between constructs and their indicators are consistent across groups, with all other parameters freely estimated.
2. Weak invariance: Assumes that factor loadings of indicators to their corresponding constructs are equal across groups, in addition to maintaining the overall pattern.
3. Strong Invariance: Adds the assumption that item intercepts are equal across groups, along with the restrictions of previous levels.
4. Strict Invariance: Imposes the most restrictions by assuming that items' error variances are equal across all groups.

After assessing these four types of MI, SI is measured by applying restrictions to the structural model. For assessing SI, all model parameters, together with structural weights, covariances and residuals, are fixed to be equal across groups. Following the proposal of de Oña (2022), all MIs are applied to the measurement components of the structural model, and the degradation caused by SI is calculated by comparing the fit of models with strict and structural invariances [70].

5. Results and discussion

5.1. PCA

In this research, PCA confirms that six components, including S, SN, HM, PEOU, PU, and ATT had eigenvalues above 1; however, as the eigenvalue of BI was slightly lower than 1 (0.949), it was included in the measurement model, aligning with TAM's theoretical structure of four components. After this step, EFA using a varimax rotation further confirms the factors with loadings over the 0.7 cutoff, a commonly used threshold [62]. All factor loadings exceeded 0.7, which is ideal, except for ATT4 (0.665), which was within the acceptable range of 0.6–0.7. This preliminary decision was made considering that final evaluations would be refined through Confirmatory Factor Analysis (CFA), which assigns indicator variables to specific constructs, reducing cross-loadings [58]. Thus, a measurement model with seven constructs was designed to evaluate the constructs' accuracy. "Goodness-of-fit" (GOF), construct validity and reliability measures are provided in Table 2.

The results of the model showed all items had factor loadings higher than 0.7 except for item S1 (0.69), which was retained within the model, complying with Hair et al. (2013). Loading factors between 0.5 and 0.7 are permissible as long as the model demonstrates an acceptable GOF [58]. Removing S1 resulted in a weaker conceptual representation of the Shame construct without improving model fit. Given that composite reliability (CR = 0.81) and AVE confirmed validity, S1 was retained in the final model.

"Cronbach's alpha" and CR values above 0.7 confirmed the reliability of all components. Furthermore, all AVEs are well higher than

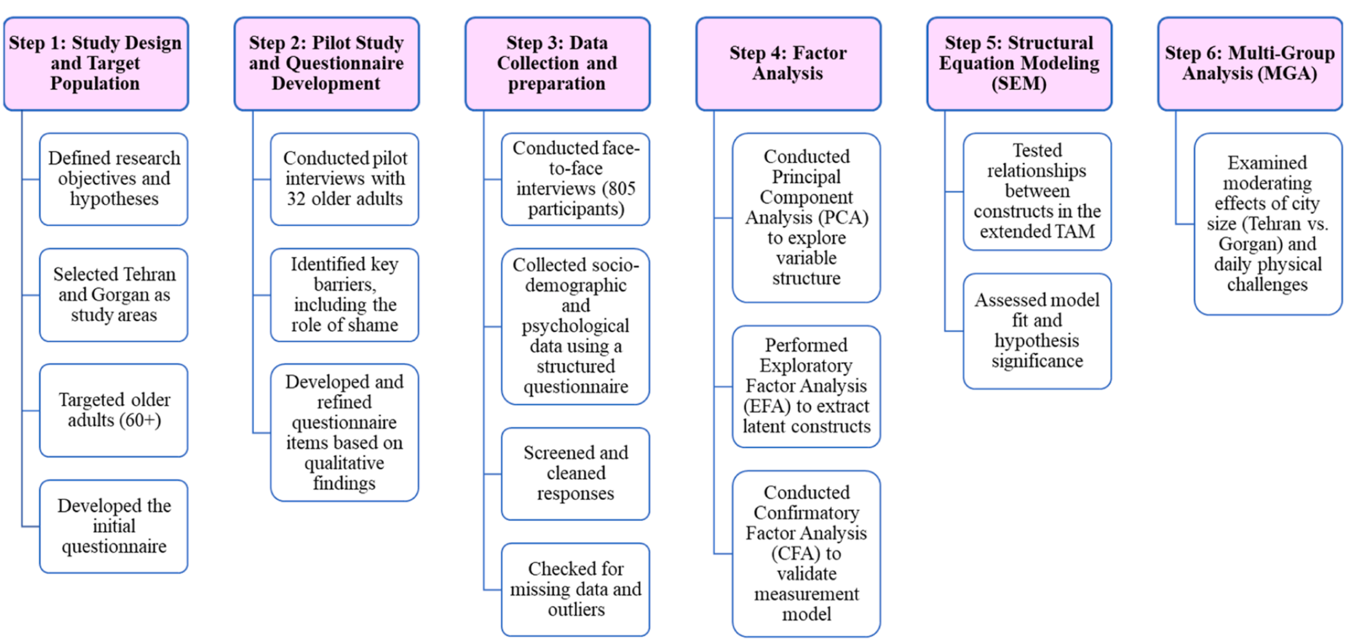

Fig. 2. Overview of the Methodological Steps.

Table 2
"Measurement model" results with "goodness-of-fit", "construct validity" and "reliability measures".

Component	Item	Estimate	SE	Z-value	Std. Coef.	R^2	AVE	CR	α
PEOU	PEOU2	1.00			0.92	0.90	0.85	0.97	0.96
	PEOU1	0.97	0.02	51.09	0.95	0.85			
	PEOU3	0.98	0.02	42.12	0.87	0.76			
	PEOU4	0.99	0.02	51.4	0.93	0.86			
PU	PU1	1.00			0.85	0.72	0.78	0.94	0.93
	PU2	1.04	0.03	35.32	0.92	0.85			
	PU3	0.99	0.03	33.14	0.89	0.79			
	PU4	1.03	0.03	32.34	0.87	0.77			
SN	SN1	1.00			0.95	0.90	0.92	0.99	0.97
	SN2	1.02	0.02	61.11	0.96	0.92			
	SN3	1.02	0.02	62.25	0.96	0.93			
HM	HM1	1.00			0.85	0.73	0.70	0.88	0.87
	HM2	1.05	0.03	30.85	0.90	0.81			
	HM3	1.00	0.04	24.19	0.75	0.56			
S	S1	1.00			0.69	0.48	0.71	0.89	0.87
	S2	1.20	0.05	22.88	0.91	0.83			
	S3	1.23	0.05	22.87	0.91	0.82			
ATT	ATT1	1.00			0.90	0.81	0.83	0.97	0.95
	ATT2	1.02	0.02	44.77	0.94	0.87			
	ATT3	0.99	0.02	44.46	0.93	0.87			
	ATT4	0.98	0.03	38.67	0.88	0.78			
BI	BI1	1.00			0.91	0.82	0.89	0.99	0.96
	BI2	1.06	0.02	49.40	0.96	0.92			
	BI3	1.07	0.02	49.61	0.96	0.92			
Chi-square (df)	1086.97 (231)								
RMSEA	0.068								
CFI	0.960								

0.5, representing a high level of "construct validity'. Finally, the RMSEA (0.068) and CFI (0.960) values were consistent with the recommended cut-off values (<0.07 and > 0.90, respectively), indicating the measurement model fits the data well.

Specifically, to ensure the validity of the "Shame" construct, we conducted tests for both convergent validity and discriminant validity. Convergent validity was evaluated by examining the Factor Loadings and AVE for the "Shame" construct. The factor loadings for all items measuring "Shame" exceeded the threshold of 0.5, indicating strong relationships between the items and the construct. Furthermore, the AVE for "Shame" was above the recommended threshold of 0.5, providing evidence of acceptable convergent validity. To assess discriminant validity, the Fornell-Larcker criterion was applied, comparing the square root of the AVE for each construct with the correlations between constructs [49]. The results confirmed that "Shame" is distinct from other constructs in the model, including Subjective Norms (SN). Accordingly, these robust constructs were used in the Structural Equation Model (SEM) to assess the study hypotheses.

5.2. Structural model

To ensure an adequate sample size for SEM, we followed recommendations from Monte Carlo simulations by Wolf et al. (2013) [72], suggesting that for models with moderate complexity (3–6 latent variables, 10–20 indicators), sample sizes between 200 and 500 are sufficient for stable and unbiased parameter estimates. Since our model contains multiple latent constructs and our sample size ($n = 805$) exceeds this threshold, we are confident in the reliability of our results. Furthermore, all path coefficients' standard errors in AMOS were within acceptable ranges, indicating stable and well-estimated parameters.

To mitigate potential overfitting, we monitored model's fit indices (RMSEA, CFI) to ensure an appropriate balance between model complexity and parsimony. Since our final model achieved an acceptable fit without excessive parameterization, overfitting was not identified as a concern.

The structural model, based on the hypotheses outlined in Section 2, is presented in Fig. 3. Our preliminary analysis indicated that "Shame", as a mediator, improved model fit (Table A4). This suggests that external shame is a key psychological mechanism through which social influences impact technology adoption among older adults; therefore, it is the focus of this paper.

According to Table 3, the majority of the structural relationships have moderate to large effect sizes. S is significantly affected by SN (−0.33), SN positively affects PU, PEOU, and BI through the mediator S. The effect of SN on these components is supported by theory in the acceptance model of e-scooters [46]. S also affects ATT through the mediator, HM ($-0.36 \times 0.40 = -0.14$). Furthermore, the relationships between PU, PEOU, ATT and BI are supported by the original TAM model. The negative impact of S on PU, PEOU, and HM can be understood through psychological mechanisms. First, the use of mobility scooters may be seen as a loss of dignity, as older adults view them as symbols of frailty or dependency [73], a perception that hinders adoption, despite its practical benefits. Second, fear of social judgment plays a significant role, particularly in cultures focused on communal perceptions. Older adults may avoid using mobility scooters to prevent being labeled as "disabled" or "old". Finally, internalized beliefs about aging, and notions that older adults should not rely on assistive devices, can further exacerbate shame [38]. These psychological processes collectively contribute to shame's negative influence on technology acceptance.

5.3. Assessing the added explanatory power of shame (S)

To evaluate the contribution of "Shame" (S) in explaining mobility scooter acceptance, we compared two structural models: with and without S. The results (Table 4) indicate that introducing S led to a notable increase in the variance explained (R^2) for key constructs:

These findings confirm that external shame plays a significant role in shaping attitudes and behavioral intentions, by moderating the effects of social influence and emotional responses.

Moreover, introducing S altered the path coefficients of key relationships (Table A4). In the model without S:

- SN's influence on ATT became non-significant, indicating that SN alone does not directly shape attitudes but rather exerts its effect through emotional responses such as shame.

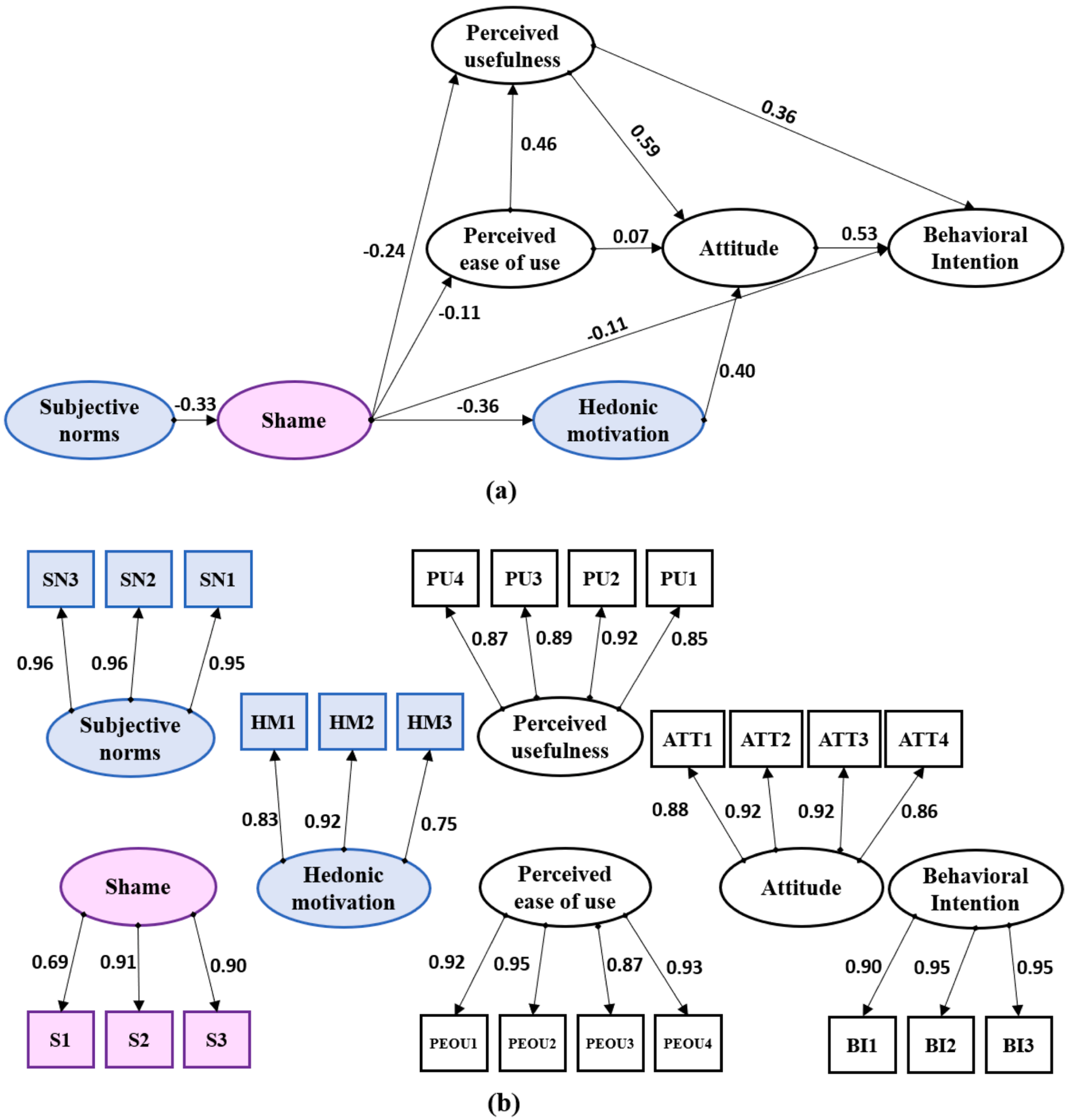

Fig. 3. Structural equation modeling utilized in the study, comprising a) the structural component and b) the measurement component.

- SN's influence on BI remained weak (0.063), suggesting that social pressure alone has little direct impact on adoption unless emotions like Shame mediate this relationship.
- SN's influence on PU (0.098) remained low, reinforcing that social norms do not strongly affect perceived usefulness in the absence of Shame.
- PU's influence on ATT (0.599) and PU's influence on BI (0.365) remained stable, suggesting that PU remains a key determinant of adoption, but Shame enhances the psychological mechanisms underlying these relationships.

These findings demonstrate that traditional TAM/UTAUT factors do not fully capture the social and emotional barriers to mobility scooter adoption. Shame serves as a critical psychological mechanism that mediates the effects of social influence on perceived usefulness, emotional response, and ultimately, adoption behavior. Retaining S in the final model provides a more comprehensive framework for understanding mobility scooter acceptance among older adults, particularly where social stigma plays a significant role in technology adoption.

5.4. MGA

Results of the variables with at least one type of MI or SI are presented in Table 5. Accordingly, for variables "City" and "Frequency of

Table 3
Structural model results.

			Estimate	S.E.	z-value	P-value	Std. Coef.
S	←	SN	−0.30	0.03	−8.68	<0.01	−0.33
PEOU	←	S	−0.11	0.04	−2.96	<0.01	−0.11
PU	←	PEOU	0.31	0.02	13.64	<0.01	0.46
PU	←	S	−0.16	0.02	−6.85	<0.01	−0.24
HM	←	S	−0.24	0.03	−9.02	<0.01	−0.36
ATT	←	PU	0.57	0.03	17.22	<0.01	0.59
ATT	←	HM	0.41	0.03	13.96	<0.01	0.40
ATT	←	PEOU	0.04	0.02	2.25	<0.02	0.07
BI	←	ATT	0.63	0.04	16.49	<0.01	0.53
BI	←	PU	0.41	0.04	11.52	<0.01	0.36
BI	←	S	−0.09	0.02	−4.68	<0.01	−0.11
Chi-square (df)		1459.54 (241)					
RMSEA		0.0791					
CFI		0.943					
R^2 (S)	0.108		R^2 (PU)		0.294		
R^2 (PEOU)	0.012		R^2 (ATT)		0.600		
R^2 (HM)	0.131		R^2 (BI)		0.734		

Table 4
Increase in the variance explained (R^2) for key constructs with the addition of Shame.

Dependent Variable	R^2 Without Shame (S)	R^2 With Shame (S)	Change (+ %)
PEOU	0.007	0.012	+0.5 %
HM	0.049	0.131	+8.2 %
PU	0.248	0.294	+4.6 %
ATT	0.578	0.600	+2.2 %
BI	0.714	0.734	+2 %

having difficulty in daily activities", there is at least one invariance that degrades the fit of the model significantly. The results indicated configural and weak invariance across both moderators, confirming that the constructs were measured similarly across groups. However, strong invariance did not fully hold, suggesting that item intercepts varied between groups, which may introduce minor response biases in latent mean comparisons.

Additionally, structural invariance was not supported, meaning that the relationships between constructs differed across groups. This validates the need for multi-group analysis (MGA), confirming that the effects of key variables vary depending on city size and mobility difficulty.

The levels of invariance that did not hold are outlined below:

For city size:

- Strong Invariance: Not held; intercepts differ across small and large cities.
- Strict Invariance: Not held; indicating differences in residuals.
- Structural Invariance: Not held; relationships between constructs may not be equivalent across city sizes.

For difficulty in Daily Activities:

- Strict Invariance: Not held; residuals differ across this moderator.
- Structural Invariance: Held; relationships between constructs were consistent across this moderator.

Thus, two variables, "City" and "Frequency of having difficulty in daily activities" entered SEM-MGA as moderator variables.

As full strong invariance was not achieved, the MGA results should be interpreted cautiously. Although factor loadings were equivalent across groups, the presence of intercept differences suggests that response tendencies may vary between city sizes. However, the lack of structural invariance confirms that certain relationships vary significantly across groups, justifying the need for moderation analysis. This limitation does not undermine the validity of the moderation analysis but highlights the importance of contextual factors in shaping attitudes toward mobility scooters.

Table 6 shows the SEM-MGA results for "City.", revealing a notable finding: the impact of SN and consequently S on other constructs is significantly more pronounced in Gorgan as a small city. The role of social factors, cultural norms and impediments and their impacts on older people's attitude toward transportation have been found significant in previous studies [2]. According to Hoque & Sorwar [50] when it comes to subjective norms or social influence, older individuals are mostly affected by their family members and close friends. In this research, 74 % of the participants reported living with their families (Table A1); this proportion was higher in Gorgan (80.83 %) compared to Tehran (66.91 %). This higher proportion suggests that social influence may be stronger in smaller towns.

As S is directly affected by SN, the negative impacts of S on PU (−0.54), PEOU (−0.33), HM (−0.54), and BI (−0.28) are more pronounced in Gorgan. This contrast demonstrates how city size influences social influence and shame in mobility scooter adoption. In smaller cities l, Subjective Norms significantly drive Shame, intensifying emotional barriers through heightened social judgment and gossip [33]. This

Table 5
Measurement and structural invariances results.

Variable	Type of invariance	Chi-square	df	CFI	ΔChi-square	Δdf	ΔCFI
City	Configural	2184.653	482	0.931			
	Weak	2243.582	499	0.929	58.929	17	0.002
	Strong	2649.076	523	0.914	405.494	24	**0.015**
	Strict	5807.782	547	0.787	3158.706	24	**0.127**
	Structural	6144.559	564	0.774	336.777	17	**0.013**
Having difficulty in daily activities	Configural	4217.849	806	0.848			
	Weak	4264.401	823	0.847	46.552	17	0.001
	Strong	4343.972	847	0.845	79.571	24	0.002
	Strict	4747.25	871	0.828	403.278	24	**0.017**
	Structural	4803.37	888	0.826	56.120	17	0.002

Table 6
SEM-MGA results for City.

			Estimate	S.E.	z-value	P-value	Std. Coef.
Tehran							
S	←	SN	−0.13	0.03	−3.79	<0.01	−0.22
PEOU	←	S	−0.09	0.07	−1.26	0.21	−0.07
PU	←	PEOU	0.41	0.04	10.17	<0.01	0.55
PU	←	S	−0.06	0.05	−1.38	0.17	−0.07
HM	←	S	−0.19	0.05	−3.61	<0.01	−0.23
ATT	←	PU	0.74	0.06	12.05	<0.01	0.76
ATT	←	HM	0.30	0.04	6.77	<0.01	0.28
ATT	←	PEOU	0.00	0.03	−0.05	0.96	0.00
BI	←	ATT	0.86	0.07	13.21	<0.01	0.84
BI	←	PU	0.09	0.05	1.70	0.09	0.09
BI	←	S	−0.07	0.03	−2.66	0.01	−0.08
Gorgan							
S	←	SN	−0.49	0.06	−8.09	<0.01	−0.39
PEOU	←	S	−0.33	0.05	−6.7	<0.01	−0.33
PU	←	PEOU	0.14	0.03	4.99	<0.01	0.21
PU	←	S	−0.36	0.03	−11.72	<0.01	−0.54
HM	←	S	−0.37	0.03	−11.61	<0.01	−0.54
ATT	←	PU	0.41	0.04	10.58	<0.01	0.41
ATT	←	HM	0.53	0.04	14.13	<0.01	0.52
ATT	←	PEOU	0.04	0.02	1.62	0.1	0.06
BI	←	ATT	0.48	0.05	10.55	<0.01	0.40
BI	←	PU	0.40	0.05	8.32	<0.01	0.33
BI	←	S	−0.23	0.03	−7.37	<0.01	−0.28
Tehran		**Gorgan**				**Tehran**	**Gorgan**
R^2 (S)	0.049	0.152		R^2 (PU)		0.313	0.407
R^2 (PEOU)	0.005	0.109		R^2 (ATT)		0.669	0.603
R^2 (HM)	0.053	0.296		R^2 (BI)		0.855	0.726
RMSEA		0.066					
CFI		0.931					

reflects stronger norm enforcement in close-knit settings. Conversely, in Tehran, a larger city with heterogeneous populations, weaker ties and diverse norms lessen Shame's impact, promoting tolerance for new behaviors [74]. This suggests urban scale moderates psychological barriers, with larger cities reducing social pressures. However, this is a double-edged sword: smaller communities may also encourage adoption when respected figures endorse scooters, offsetting shame with support.

External shame is magnified in collectivist cultures where individuals are more affected by how they are perceived by others [75]. In Gorgan, with frequent community interactions, the fear of stigma may be more intense compared to Tehran's more individualistic and anonymous environment.

Contextual factors also contribute to the pronounced impact of Shame on Gorgan. First, 60.60 % of respondents in Gorgan reported a monthly income of 5.5–11.5 million Tomans, compared to 40.35 % in Tehran (Table A1), indicating a lower average income in Gorgan. This economic disparity may exacerbate feelings of shame associated with using assistive devices, as older adults in smaller cities may perceive mobility scooters as unaffordable or impractical [76].

Second, access to healthcare services, often more limited in smaller cities than in larger ones, may play a significant role. Older adults in smaller cities may have fewer opportunities to engage with healthcare providers who could educate them about the benefits of mobility aids, thereby reducing stigma. Furthermore, the lack of infrastructure, such as accessible sidewalks and public transportation options, may exacerbate feelings of shame. Users may feel more conspicuous and vulnerable in environments that are not designed to accommodate their needs [9,17]. These factors, combined with the close-knit social structures of smaller cities, create a unique context where shame becomes a more significant barrier to technology adoption.

The comparison of relationships between Tehran and Gorgan reveals other distinct patterns in mobility scooter adoption. In Tehran, practicality and positive attitudes are the strongest drivers of adoption, with strong relationships (β > 0.5). This suggests that older adults in large cities prioritize the practicality of scooters when forming adoption intentions. In contrast, in Gorgan, emotional factors such as enjoyment and Shame play a more significant role, with moderate to strong relationships (β > 0.3). S has a moderate negative effect on PU (β = −0.54) and HM (β = −0.54) in Gorgan, indicating that social judgment and stigma significantly reduce the perceived practicality and enjoyment of scooters in small cities. In contrast, in Tehran, Shame has only a weak effect (β = −0.07), indicating that social judgment plays a minimal role in shaping perceptions of practicality in large cities. Besides, In Gorgan, the effect of HM on ATT was stronger (0.52) compared to Tehran (0.28), strengthening that in smaller cities, emotional factors like enjoyment and shame play a more significant role in shaping attitudes toward mobility scooters.

The higher effect size of PU on ATT in Tehran (0.76) compared to Gorgan (0.41) reflects the urban context where practicality strongly influences attitudes toward adopting new transport modes. This difference underscores that practicality is a critical determinant of transportation choices in larger cities, possibly due to the unique mobility challenges posed by Tehran's transport environment. In Tehran, public transport options exist but are often not age-friendly, and present physical and accessibility barriers for older adults [2]. These limitations, coupled with severe congestion and overcrowding [54], reduce the practicality of public transport, potentially leaving older adults more dependent on informal support, such as rides from family or friends, when other options fail. Although Table A1 shows similar reliance on relatives in Tehran (23.61 %) and Gorgan (21.67 %), Tehran's urban complexity may amplify the impact of these challenges, making alternatives like mobility scooters particularly appealing for enhancing independence.

Although only 13.56 % of respondents in Tehran identified public transport as their primary mode of transport, this rate is significantly higher than in Gorgan, where public transport usage was nearly nonexistent (Table A1). In cities like Tehran, where public transport serves as a supplementary but critical option, the practicality of alternative modes to access this system, such as mobility scooters, becomes even more significant. Mobility scooters can bridge the gap between the limitations of public transport and the need for flexible, independent mobility. By enabling elderly users to make short trips or access public transport hubs more easily, scooters address the barriers posed by inadequate public transport infrastructure. This aligns with [29], who found that preferences for autonomous vehicles vary across small, medium, and large metropolitan areas, with urban residents prioritizing practical transport solutions due to greater mobility demands and reliance on public systems.

Elderly individuals in larger cities are more likely to perceive mobility scooters as a viable solution to the challenges of public transport and the dependency on family and friends for rides. If mobility scooters are perceived as practical for flexible trip-making, they can promote equitable mobility and social sustainability. Additionally, this shift could reduce reliance on car rides, contributing to environmental sustainability through decreased fossil fuel consumption.

Table 7 represents the results of SEM-MGA for “Frequency of having difficulty in daily activities”. Mobility difficulties are an inevitable part of aging [10] and should not be ignored. In this research, among 805 respondents, 320 respondents reported frequent difficulties, 277 reported occasional, and 208 reported rare difficulties (Table A1). Such mobility challenges degrade both physical and mental health due to limitations in daily activities [3].

Based on the findings, PEOU significantly affects PU across all subgroups, though the effect is strongest for elders with frequent physical difficulties. Using transport modes that require learning new skills can be challenging for older individuals [3], particularly when physical capabilities are reduced. However, if assured that mobility scooters are easy to learn and use, even those with minimal difficulties find them practical. Additionally, S negatively impacts PEOU and PU in all groups, suggesting emotional barriers persist despite fewer physical challenges.

Besides, for those with frequent difficulties, the effect size of PU on attitude (0.68) is notably higher than for those with fewer challenges. This demonstrates that older people who are more physically-challenged have a more optimistic perception towards mobility aids if they are found practical. The result is in line with various studies suggesting that the rate of mobility scooter or powered wheelchair usage increases with the intensity of health problems [16,17,77]. It may be due to the fact that by using mobility aids, they can remain active members of society, which may not be possible otherwise. Especially in car-dominated countries like Iran, where driving is integral to daily life, physical conditions that render individuals unable to drive safely often leave them unable to meet their basic needs [2,10]. Thus, the practicality of mobility scooter becomes important and gives the older population a more positive perception of them.

The questionnaire also included additional variables that, when tested through MGA approaches, did not have a significant influence on behavioral intention (listed in Table A1).

5.5. The broader role of shame

The role of Shame in technology acceptance is likely influenced by broader cultural and social contexts. In collectivist cultures, like Iran, China, and India, shame may be more distinct due to stronger social

Table 7
SEM-MGA results for frequency of having difficulty in daily activities.

			Estimate	S.E.	z-value	P-value		Std. Coef.
Rarely								
S	←	SN	- 0.01	0.09	−0.06	0.96		0
PEOU	←	S	−0.14	0.04	−3.46	<0.01		−0.27
PU	←	PEOU	0.44	0.08	5.31	<0.01		0.39
PU	←	S	−0.14	0.04	−3.67	<0.01		−0.20
HM	←	S	−0.12	0.04	−2.81	<0.01		−0.28
ATT	←	PU	0.40	0.06	2.64	<0.01		0.48
ATT	←	HM	0.41	0.06	6.91	<0.01		0.42
ATT	←	PEOU	0.16	0.06	7.20	<0.01		0.18
BI	←	ATT	0.48	0.08	6.12	<0.01		0.40
BI	←	PU	0.49	0.07	7.51	<0.01		0.50
BI	←	S	−0.02	0.03	−0.67	0.50		−0.04
Sometimes								
S	←	SN	−0.41	0.07	−6.26	<0.01		−0.39
PEOU	←	S	−0.17	0.05	−3.14	<0.01		−0.20
PU	←	PEOU	0.23	0.04	5.53	<0.01		0.32
PU	←	S	−0.22	0.04	−5.99	<0.01		−0.36
HM	←	S	−0.24	0.04	−6.37	<0.01		−0.41
ATT	←	PU	0.49	0.06	8.46	<0.01		0.47
ATT	←	HM	0.46	0.06	7.81	<0.01		0.40
ATT	←	PEOU	0.06	0.04	1.53	0.13		0.08
BI	←	ATT	0.51	0.06	9.11	<0.01		0.46
BI	←	PU	0.44	0.06	7.32	<0.01		0.37
BI	←	S	−0.12	0.03	−3.70	<0.01		−0.16
Usually								
S	←	SN	−0.30	0.05	−6.65	<0.01		−0.42
PEOU	←	S	0.04	0.08	0.54	0.59		0.03
PU	←	PEOU	0.43	0.03	13.60	<0.01		0.63
PU	←	S	−0.19	0.04	−4.47	<0.01		−0.22
HM	←	S	−0.27	0.05	−5.08	<0.01		−0.33
ATT	←	PU	0.68	0.05	13.58	<0.01		0.69
ATT	←	HM	0.35	0.04	8.81	<0.01		0.34
ATT	←	PEOU	0.02	0.03	0.69	0.49		0.03
BI	←	ATT	0.73	0.06	12.77	<0.01		0.60
BI	←	PU	0.35	0.05	6.51	<0.01		0.29
BI	←	S	−0.11	0.03	−3.33	<0.01		−0.11
	Rarely	**Sometimes**	**Usually**			**Rarely**	**Sometimes**	**Usually**
R^2 (S)	0.384	0.149	0.177	R^2 (PU)		0.675	0.275	0.442
R^2 (PEOU)	0.388	0.039	0.001	R^2 (ATT)		0.725	0.484	0.649
R^2 (HM)	0.559	0.170	0.109	R^2 (BI)		0.885	0.677	0.766
RMSEA		0.070						
CFI		0.861						

norms, family ties, and hierarchical structures. For example, in China, older adults often face significant social pressure to conform to society's expectations, intensifying feelings of Shame when using assistive devices [78]. This contrasts with individualist cultures, such as those in the US or Western Europe, where independence is prioritized, potentially reducing the impact of Shame on technology adoption. Additionally, negative perceptions from other road users, such as drivers or pedestrians, can amplify feelings of shame or stigma associated with scooter use [9]. Older adults may avoid using scooters if they perceive other road users view them as obstacles or safety hazards.

Shame can contribute to transport-related social exclusion, specifically in developing countries where assistive devices may be stigmatized as symbols of dependency or frailty. In India, older adults who rely on mobility aids often face social isolation and exclusion from public spaces due to negative perceptions of disability [7]. These findings highlight the need for culturally sensitive interventions to address Shame and promote the acceptance of assistive technologies in diverse contexts.

By comparing our findings with studies from other regions, we can better understand how Shame operates across different cultures. In areas, where communal traditions are strong, older adults may experience Shame when using mobility scooters due to concerns about burdening their families or communities. In contrast, in more individualist societies like Australia, older adults may prioritize practicality and independence over social judgment, reducing the influence of Shame on adoption decisions [16]. These cross-cultural comparisons underscore the importance of tailoring policies and interventions to address the unique psychological and social barriers faced by older adults in different regions.

5.6. Future research directions

While this study highlights the significant role of 'Shame' and social influence in mobility scooter acceptance, future research should explore additional factors that may impact attitudes and intentions. For example, facilitating conditions, such as infrastructure for safe scooter use, could play a critical role in adoption. Gitelman et al. [17] found that inadequate infrastructure, such as a lack of dedicated lanes or accessible pathways, can create anxieties among potential users and hinder scooter adoption.

Similarly, Future studies should examine how perceptions from other road users, such as drivers or pedestrians, interact with social norms and shame to shape mobility scooter acceptance, particularly in diverse urban and rural contexts.

Future research could explore rural-urban parallels in mobility scooter adoption, building on [79], who found that factors influencing shared mobility in rural Austrian towns – such as convenience and accessibility – mirror those in urban settings, suggesting broader applicability of contextual analyses. Studies could also explore separate impacts of internal and external shame on mobility scooter adoption across different cultural contexts, to deepen the understanding of the emotional factors at play.

6. Policy implications

This study highlighted key emotional and practical barriers to mobility scooter acceptance among older adults, particularly the significant role of shame and subjective norms. Given the importance of social sustainability that favors social inclusion and transport equity, many countries, such as Germany, Italy, and Canada, have implemented equity policies [2]. To address these barriers and enhance scooter adoption in Iran, the following recommendations are proposed:

6.1. Awareness and education campaigns

Policymakers should implement public awareness campaigns to reduce the stigma surrounding mobility scooter use among older adults. These campaigns should emphasize the benefits of scooters, such as greater independence, improved mobility, and a better quality of life. Educational initiatives targeting both older adults and their families are crucial to fostering a supportive environment for mobility scooter users. This aligns with previous research indicating that social influence has a critical role in the adoption of assistive technologies [80,81]. In Israel, older users reported that scooters improved their quality of life and provided better access to services, but many expressed concerns about safety and lack of infrastructure [17]. Campaigns could address this through success stories and safety education. Such informational efforts should be paired with experiential strategies to maximize effectiveness.

6.2. Hands-On experience and living labs

To overcome psychological barriers like Shame and enhance Perceived Usefulness, hands-on opportunities should be introduced. Public trials and low-cost trial rentals, subsidized by authorities, allow older adults to test scooters in real-world settings, reducing stigma through familiarity [16]. In Tehran, trials could focus on urban mobility challenges, such as accessing public transport hubs. In Gorgan, where Shame is pronounced, community-based living labs – collaborative spaces for testing innovations [82] – could involve families and local leaders to normalize scooter use and shift norms. Evidence from Australia shows trial experiences increase confidence and adoption among older adults [16], while living labs in Europe have successfully co-designed mobility solutions with users [82]. These initiatives complement awareness campaigns and offer more than passive information.

6.3. Community engagement and role models

The effects of subjective norms on intention and behavior can be a double-edged sword, being able to have both positive and negative effects [83]. In smaller cities, where subjective norms and shame have a stronger influence, local governments should collaborate with respected community figures, such as respected elders, or local celebrities, to serve as role models for mobility scooter use, and promote positive perceptions of mobility. These role models can help shift the narrative from scooters being associated with old age or disability to representing independence and modernity, altering the negative impacts of subjective norms into constructive ones. This approach builds on the importance of social acceptance and behavioral modeling in technology adoption [41]. In the UK, local governments have partnered with senior citizens' associations to promote the use of assistive devices. In these initiatives, older adults who use mobility scooters were invited to share their stories at community centers, and public events, helping to normalize their use and reduce stigma [15].

6.4. Infrastructure and accessibility improvements

In large metropolitan areas like Tehran, where practical factors such as perceived usefulness are more critical, urban planning should prioritize infrastructure improvements. This includes ensuring the availability of ramps, elevators, and accessible public transport systems that cater to mobility scooter users. Clear traffic regulations for scooter users should also be established, along with dedicated scooter lanes where feasible, to enhance safety and usability [84]. Generally, streets should be designed inclusively, serving the needs of marginalized and underserved groups [3].

For instance, based on observations in Israel, scooters traveling on roads often disturbvehicle traffic, especially on dual-carriageway roads. Cities could implement traffic calming measures, such as reduced speed limits in areas with high scooter usage or the creation of shared zones where vehicles and scooters coexist at low speeds [17]. Additionally, in Victoria, Australia, local governments have installed curb ramps and improved accessibility features at pedestrian crossings to facilitate scooter use, which could serve as a model for Tehran [85]. These improvements not only facilitate mobility but also support broader urban sustainability goals.

6.5. Financial support mechanisms

Although our empirical analysis did not include cost as a factor in the model, the recommendation for financial support mechanisms is informed by a broader body of literature on assistive technology. To encourage adoption, governments should provide financial incentives such as subsidies, tax reductions, or transport discounts for mobility scooter purchases. Research has shown that financial assistance can markedly influence the adoption of assistive technology among lower income older adults [76]. These measures would alleviate the cost barrier and increase the attractiveness of scooters as a mobility solution.

6.6. Targeted interventions for smaller communities

Implementing advanced transportation strategies from large cities in rural towns is often ineffective or impractical [79]. In smaller communities, policy interventions should focus on alleviating emotional barriers linked to shame and social norms, enabling families and caregivers— as primary influencers of older adults' attitudes—to help overcome resistance to scooter adoption. In Finland, for example, family and close friends play a crucial role in building initial trust in assistive technology among older adults [86]. Given that 74 % of older adults in our study reported living with their families, family attitudes could significantly influence adoption decisions. Building on this, family-centered interventions, such as family-based awareness campaigns, educational programs through community health centers, senior citizens' associations, or online platforms, can help address emotional barriers by educating families and caregivers.

6.7. Public behavior and inclusivity campaigns

A broader societal change is needed to encourage respect and inclusivity for mobility scooter users. Public education campaigns should emphasize mobility needs and respectful behavior toward older scooter users. This could mitigate feelings of shame or embarrassment experienced by users and contribute to a more inclusive environment for all mobility-impaired individuals. Additionally, governments can establish "ambassador programs" where older adults who actively use mobility scooters are trained to advocate for their benefits within their communities. These ambassadors can provide peer support, answer questions, and address concerns. Similar programs have been implemented in the UK, where using alternative modes of transport has successfully increased acceptance and usage among older adults [15].

7. Conclusions

Achieving sustainable and equitable transportation requires not only the development of novel technologies but also the effective integration of existing solutions tailored to diverse societal contexts. The current study presented factors affecting the priori acceptance of mobility scooters among the older citizens of a large and a small city. Overall, 805 valid questionnaires were obtained via face-to-face interviews with older adults aged above 60 in both cities. The proposed model of this study was extended TAM, with additional constructs of subjective norms, hedonic motivation, and shame. Also, SEM-MGA was applied to consider the effects of moderators, city size and having difficulty in daily activities, on relationships between latent variables.

Findings indicate that the novel construct "Shame" significantly predicts the acceptance of mobility scooters among the older population. Notably, smaller cities like Gorgan exhibit a stronger correlation between the impact of "Subjective Norms" and, subsequently, "Shame" on other constructs compared to larger cities like Tehran, where "Perceived Usefulness" exhibits a stronger effect size on attitude. These insights suggest that while practical considerations drive scooter acceptance in larger cities, social influences are more critical in smaller communities.

Implementing the policy recommendations suggested in this study will address both the practical and emotional challenges associated with mobility scooter adoption among older adults, improving their quality of life and public health outcomes by boosting inclusivity. By tackling the stigma and creating supportive communities and infrastructure, policymakers can facilitate greater acceptance and usage of mobility scooters, particularly in developing low-income countries. This approach may also change the travel behavior of older adults from relying on cars, whether as the driver or passenger, to mobility scooters. 54 % and 74 % of respondents in Tehran and Gorgan, respectively, were car-dependent (Table A1) and potential users of mobility scooters. Usage of mobility scooters favors social sustainability, improving mobility equity by helping the elderly be active members of society again, as well as reducing their reliance on taking rides from family, and friends that accounts for environmental sustainability by reducing car usage.

It should be noted that while mobility scooters enhance independence and social inclusion, potential drawbacks should be considered. Overreliance on mobility scooters may reduce physical activity, impacting walking ability and overall health. Although no short-term negative effect on physical functionality has been seen [87], its long-term effect on its users' physical abilities needs further studies. Policymakers should consider strategies encouraging both mobility assistance and the maintenance of physical activity.

This study provides a basis for subsequent studies on mobility scooter acceptance. Conducted in a single low-income country, similar studies across diverse nations could provide broader insights. Future research could explore rural-urban disparities and include direct scooter experience for participants. One limitation of this study is the use of a video to introduce mobility scooters, which may have subtly influenced participants' perceptions. Future research could address this by incorporating real-world trials or interactive demonstrations for a more natural setting. Also, the sampling strategy focused on older adults who were still able to access public or semi-public spaces such as clinics, local shops, and parks. As such, homebound individuals or those with more severe mobility limitations were not included. While this aligns with our study objective—to examine the willingness of potential users to adopt mobility scooters—it limits the generalizability of findings to the broader elderly population. Future research should consider complementary methods to reach less mobile or homebound older adults, whose needs and attitudes may differ significantly. Additionally, extending the TAM model to include components like habit and facilitating conditions could enhance understanding. Future studies should also examine mobility scooter acceptance among diverse user groups beyond the older generation, including those facing temporary or permanent mobility challenges.

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CRediT authorship contribution statement

Ala Kordrostami: Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation. **Javad Esmailpour:** Writing – review & editing, Visualization, Validation, Methodology, Investigation. **Kayvan Aghabayk:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Nirajan Shiwakoti:** Writing – review & editing, Methodology, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A1, Table A2, Table A3, Table A4

Table A1
Summary of socio-demographic, travel habits, and health condition information.

Variable	Category	Number of respondents	Percentage of respondents	
City	Tehran	399	49.57	
	Gorgan	406	50.43	
			Tehran	**Gorgan**
Gender	Male	430	51.75	58.37
	Female	375	48.25	41.62
Marital status	Married	662	75.19	89.16
	Single	143	24.81	10.83
Number of children	No children	87	8.52	13.05
	One or Two	239	29.32	30.05
	Three or more	479	62.16	56.90
Life condition	Alone	93	13.03	10.07
	With a caregiver	100	16.04	8.84
	With family	596	66.91	80.83
	In a retirement home	16	4.01	0.24
Monthly income*	<2.5 MT	58	4.27	10.10
	2.5 to 5.5 MT	82	11.53	8.87
	5.5 to 11.5 MT	407	40.35	60.60
	>11.5 MT	258	43.86	20.44
Educational Status	Diploma and lower	489	66.67	54.93
	Bachelor and master	264	29.32	36.20
	PhD or higher	52	4.01	8.87
Trip purpose**	Work	205	28.57	22.41
	School	83	20.80	0
	Helping relatives	268	45.86	20.93
	Shopping	513	66.16	61.33
	Hanging out with relatives	715	88.72	88.91
	Hanging out with friends	521	61.15	68.22
	Having fun	438	54.88	53.94
	Visiting a doctor	634	80.95	78.60
	No leaving the house	7	1.00	0.74
Health Condition	Very good	54	7.52	5.91
	Good	251	34.59	27.83
	Not so good	322	33.58	46.31
	Bad	178	24.31	19.95
Frequency of having difficulty in daily activities	Rarely	208	31.58	20.19
	Sometimes	277	24.06	44.58
	Usually	320	44.36	35.22
Main mode of transport	Driving a personal car	338	31.15	52.70
	Taxi	71	10.55	7.14
	Taxi service	157	21.10	17.98
	Getting a ride from relatives	182	23.61	21.67
	Public transport	57	13.56	0.74
Frequency of using public transport in a week	Twice or less	574	53.88	88.42
	Three to four times	190	38.10	9.36
	Five to six times	39	7.77	1.97
	Every day	2	0.25	0.24
Price of scooter	<5.5 MT	284	28.82	41.63
	5.5 – 11.5 MT	179	25.31	19.21
	11.5 – 22.5 MT	103	14.79	10.84
	>22.5 MT	6	0.75	0.74
	Not willing to pay	223	28.82	27.59
Aim of using scooter**	Work	159	31.83	7.88
	School	118	29.32	0.25
	Helping relatives	194	42.36	6.15
	Shopping	476	67.67	50.74
	Hanging out with relatives	564	80.96	59.36
	Hanging out with friends	444	61.40	49.01
	Having fun	364	54.39	36.21
	Visiting a doctor	525	72.68	57.88
	Will not use	86	8.02	13.30
Tendency to buy scooter	Yes	573	80.70	61.58
	No	232	19.30	38.42

* MT = million Tomans (50,000Tomans ~ 1 USD).
** Multiple-select question.

Table A2
descriptive statistics of indicator variables.

Construct	Indicator variable	Mean	S.D.	item
PU	"Using mobility scooter would enable me to accomplish daily tasks more quickly."	3.11	0.842	PU1
	"Using mobility scooters would improve my efficiency for short distance trips."	3.20	0.807	PU2
	"Using mobility scooters would shorten travel time in short distance trips."	3.22	0.795	PU3
	"Overall, I would find mobility scooters useful in my daily life."	3.27	0.835	PU4
PEOU	"Learning to use mobility scooters would be easy for me."	2.70	1.099	PEOU1
	"I would find it easy to get the mobility scooter to do what I want it to do."	2.64	1.102	PEOU2
	"It would be easy to become skillful at using mobility scooter."	2.52	1.171	PEOU3
	"Overall, I find mobility scooters easy to use."	2.67	1.119	PEOU4
SN	"People who are important to me would think that I should use mobility scooters."	2.78	1.168	SN1
	"People who influence my behavior would think that I should use mobility scooters."	2.77	1.174	SN2
	"In general, people whose opinions I value would like me to use the mobility scooter."	2.81	1.169	SN3
HM	"I find using the mobility scooters to be enjoyable."	3.25	0.826	HM1
	"I find using the mobility scooters to be pleasant."	3.19	0.819	HM2
	"I have fun using the mobility scooters."	3.05	0.939	HM3
S	"I feel ashamed of using mobility scooters among people."	1.41	1.475	S1
	"In my opinion, people who use mobility scooter are very old."	1.14	1.347	S2
	"In my opinion, if I use mobility scooters people think that I am very old."	1.27	1.384	S3
ATT	"Using mobility scooter is a good idea for short distances."	3.21	0.848	ATT1
	"Using mobility scooter is a wise idea for short distances."	3.24	0.837	ATT2
	"Using mobility scooter is pleasant for short distances."	3.25	0.811	ATT3
	"Overall, I like the idea of using mobility scooter."	3.27	0.851	ATT4
BI	"Assuming that I had access to the Mobility scooters, I predict that I would use it."	3.24	0.958	BI1
	"Assuming that I had access to the Mobility scooters, I intend to use the mobility scooters for my short distance trips in the future."	3.17	0.962	BI2
	"Assuming that I had access to the Mobility scooters, I plan to use the mobility scooters for my short distance trips in the future."	3.16	0.966	BI3

Table A3
descriptive statistics of indicator variables in both cities.

		Tehran		Gorgan	
Construct	Item	Mean	S.D	Mean	S.D.
PU	PU1	3.20	0.889	3.02	0.784
	PU2	3.37	0.779	3.03	0.799
	PU3	3.35	0.784	3.08	0.784
	PU4	3.38	0.764	3.16	0.886
PEOU	PEOU1	2.98	0.983	2.43	1.139
	PEOU2	2.94	0.980	2.34	1.135
	PEOU3	2.72	1.108	2.32	1.199
	PEOU4	2.96	1.005	2.40	1.156
SN	SN1	2.57	1.369	2.98	0.887
	SN2	2.54	1.379	2.99	0.878
	SN3	2.61	1.372	3.00	0.886
HM	HM1	3.38	0.847	3.13	0.787
	HM2	3.21	0.869	3.16	0.768
	HM3	2.97	1.044	3.12	0.818
S	S1	1.85	1.517	0.99	1.298
	S2	1.51	1.414	0.78	1.170
	S3	1.75	1.363	0.80	1.233
ATT	ATT1	3.32	0.851	3.11	0.834
	ATT2	3.37	0.788	3.11	0.864
	ATT3	3.38	0.771	3.13	0.830
	ATT4	3.42	0.835	3.13	0.853
BI	BI1	3.44	0.796	3.05	1.061
	BI2	3.40	0.811	2.94	1.040
	BI3	3.40	0.805	2.93	1.053

Table A4
Structural model results without the inclusion of the construct "Shame".

			Estimate	S.E.	z-value	P-value	Std. Coef.
PEOU	←	SN	0.081	0.03	2.35	<0.02	0.086
PU	←	PEOU	0.326	0.02	13.81	<0.01	0.480
PU	←	SN	0.063	0.02	2.98	<0.01	0.098
HM	←	SN	0.138	0.02	5.92	<0.01	0.221
ATT	←	PU	0.570	0.03	2.14	<0.01	0.599
ATT	←	HM	0.413	0.03	17.16	<0.01	0.420
ATT	←	PEOU	0.042	0.02	13.98	0.032	0.065
ATT	←	SN	−0.170	0.02	−1.06	0.029	−0.28

(*continued on next page*)

Table A4 (*continued*)

			Estimate	S.E.	z-value	P-value	Std. Coef.
BI	←	ATT	0.655	0.04	17.16	<0.01	0.553
BI	←	PU	0.412	0.03	11.84	<0.01	0.365
BI	←	SN	0.045	0.02	2.90	<0.01	0.063
Chi-square (df)		1173.432 (178)					
RMSEA		0.0830					
CFI		0.949					
			R^2 (PU)		0.248		
R^2 (PEOU)	0.007		R^2 (ATT)		0.584		
R^2 (HM)	0.049		R^2 (BI)		0.718		

Data availability

Data will be made available on request.

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