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Drivers of elderly rail service passenger satisfaction: The roles of service innovation, perceived value and service quality

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Abstract

This study investigates the factors influencing elderly rail passenger satisfaction (EPS). These include service innovation (SI), perceived value (PV), and passenger service quality (PSQ). The study also develops a structural equation model (SEM) representing SRT service EPS and validates the model using empirical data. The quantitative survey used a five-level Likert-scale questionnaire. The sample consisted of 625 elderly individuals with prior experience using Thailand's railway services, selected through multi-stage random sampling. Instrument reliability and validity were confirmed. Data analysis included descriptive statistics and confirmatory factor analysis using LISREL 9.2 to test measurement and structural models. Results indicated that older passengers rated SI, PV, PSQ, and EPS at high levels. The SEM demonstrated excellent fit with empirical data and accounted for 74% of the variance in EPS. The measurement model strongly aligned with theoretical expectations. The model was validated as a comprehensive framework in understanding railway services' EPS, highlighting the significance of SI and PV. These insights offer a foundation for enhancing user experience among aging populations. The findings guide railway operators and policymakers seeking to improve public transport inclusivity, especially among elderly users in Thailand’s rapidly aging society.

Keywords: Elderly passengers, Service innovation, State Railway of Thailand (SRT), Thailand.

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1. Introduction

Population aging has been one of the most pervasive social transformations in the world in the 21st century, with the

broad demographic change evident across the Kingdom of Thailand (Figure 1). Overall, there has been a growing number of senior persons in Thailand. In particular, the aged population of 80 years or older increased significantly during 2002–2021 [1]. The proportion of Thai people aged 60 or older has risen, climbing from 10% in 2005 to 20% in 2023, and is expected to exceed 30% in 2038. Thailand is, therefore, an officially super-aged society [2].

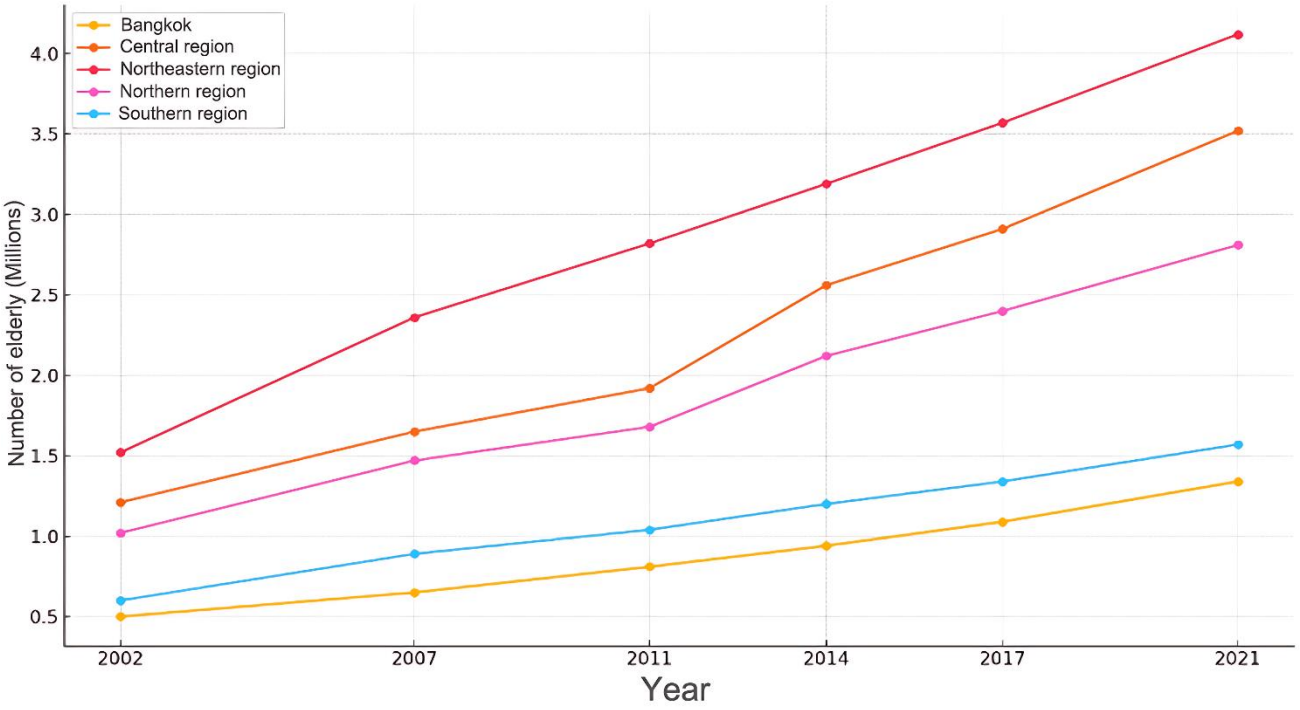

Figure 1.
Thailand's elderly population by region, 2002-2021.
Source: Grassi [1].
Figure development: The authors used Python 3.8.

This evolution gives rise to crucial policy and economic challenges. As Bandaogo and Van Doorn [3] emphasized, the aging population and continuously low fertility rates are expected to dampen long-term economic momentum by reducing the existing working-age population and population growth. Scholars further point out that these factors will lead to weaker economic growth [4-6]. Thailand could witness a decline of roughly 14.4 million workers and a 5% decrease in participation rates [7]. This demographic burden raises further hurdles for Thailand to grow out of the middle-income trap. The search for an effective and decisive strategy must address population aging and lower economic output.

In particular, as population aging proceeds, it affects public service infrastructure [8]. One of the relevant components is transportation systems, which need transformation to address the mobility needs of older adults. These people require accessible transport systems catering to their physical disabilities while maintaining independence. In this regard, Thailand's Ministry of Transport has implemented inclusive mobility in Thailand. For example, the 20-Year Transport Strategy (2017–2036) identifies the need for Universal Design (UD) to help establish a mobility system that promotes access for all user groups [9-11]. UD initiatives aim to reduce social exclusion through infrastructure improvements, inclusive policies, inter-agency coordination, and service innovation [12, 13]. Older adults' mobility is not merely optional but ensures they are not socially excluded, allowing them to maintain autonomy, health, and inclusion in community life [14-16]. As families shift to more nuclear formations and older adults increasingly live away from children, either alone or within extended households [17] they more readily rely on public transport. However, founding barriers for aged Thai people, such as confusing signage, physical inaccessibility, unassisted staff, and an unfriendly ticketing system, remain apparent, especially in the State Railway of Thailand (SRT) network [18, 19].

Globally and regionally, researchers Jahangir et al. [20] and Xie [21] have promoted inclusive mass transit systems (MTS) designed to accommodate older adults and people with disabilities. Although the country and area pockets, such as Bangkok and regional train stations like Hua Lamphong, have advanced policies and enacted pilot UD schemes within Thailand's transport hubs [22, 23]. There is still no holistic strategy to address the experience and emotional aspects of elderly travel [24].

Service innovation (SI) has become an important way to meet this challenge, which includes both technological improvements (e.g., real-time tracking, contactless ticketing, voice-based navigation) and non-technological ones (e.g., staff training, empathetic design, feedback mechanisms) [21, 25]. These innovations can not only enhance passenger service quality (PSQ) but also help build elderly passenger satisfaction (EPS) by lowering their travel-related anxiety, enhancing the overall sense of security and dignity [26].

Nonetheless, studies on Thailand's elderly passengers' travelling experiences have overlooked the function of SI and perceived value (PV). Previously related studies have examined general service quality, the business image of a company,

or user motivation [18, 19]. Nevertheless, limited research has focused on the isolated needs and relevant elements that result in their satisfaction for senior citizens, who represent a rapidly growing percentage of commuters.

This study bridges that gap by developing a conceptual model of passenger satisfaction with rail transport service innovation, service quality, and perceived value to assess such passenger satisfaction of elderly passengers in the Thai railway transportation. Data was collected from over 600 elderly passengers across five railway lines of the SRT. Structural equation modeling (SEM) was used to examine the significant predictors of satisfaction, service innovation, and perceived value.

2. Literature Review

2.1. Service Innovation (SI)

Service innovation (SI) has become important for improving user experience and creating a competitive advantage in the service industry. In the transportation sector, especially in passenger rail services for older adults, SI is a key to improving access, ease of movement, and the perception of modernity.

According to Gremyr et al. [25] SI is a compound phenomenon involving technology-based and organizational innovation with implications for service delivery and experience. In public transportation contexts, especially in the rail industry, demographic changes have fostered the growing importance of SI. As Chen et al. [27] noted, the growing share of elderly passengers calls for design and service delivery adjustments using technology such as AI. Examples of such innovations include priority seating [28] intuitive ticketing systems and voice-guided passenger interfaces. These innovations are not simply conveniences but contribute to raising the general satisfaction of older adults with exceptional mobility or cognitive needs [24].

Strategically, Wang et al. [29] defined four elements in SI. These included (1) new service concepts, referring to new ideas of service operations, structure, and content, (2) new client interfaces, which are interfaces between service providers and users, (3) new service delivery systems, which comprise the infrastructure consisting of human resources and material resources, and (4) technological options, such as mobile apps or real-time tracking technology.

Each of these factors can have a positive impact on passenger service quality (PSQ) (H2) and elderly passenger satisfaction (EPS) (H1). For example, older users find a stress-relieving and reliable service when boarding systems are designed to be user-friendly, arrival times are shared in real time, and staff are trained in age-sensitive language and demeanor. [30].

Further stressing the need for individualization and flexibility, Giannopoulou et al. [31] argued that SI, implemented carefully, can create more inclusive environments out of hard-structured public transport systems. Examples like larger digital screens, step-free infrastructure, and assisted ways to purchase tickets verify that tailored innovations can respond to physical and emotional dimensions and, as such, impact elderly satisfaction.

Importantly, not all SI activities are technology-related. Human-based improvements such as compassionate employee behavior, a consistent design vocabulary, and transparent communication are all powerful tools at a transport provider's disposal to reduce uncertainty and provide a sense of confidence [30]. These service devices for elderly travelers are especially relevant for those unfamiliar with digital tools and may be anxious about reaching their destination.

In short, service innovation creates an atmosphere that makes public transport more flexible, efficient, and emotionally calming, directly affecting passenger service quality. The first and second hypotheses are tested in this study, which are crucial to achieving satisfaction for elderly passengers.

$H_{1:}$ Service innovation (SI) → Elderly passenger satisfaction (EPS).

$H_{2:}$ Service innovation (SI) → Passenger service quality (PSQ).

2.2. Perceived Value (PV)

Perceived value (PV) is a fundamentally psychological construct in consumer satisfaction theory that has been fully and widely applied in service industries such as hospitality, healthcare, and, increasingly, public transportation. Perceived value refers to passengers evaluating service benefits relative to costs [32]. In social contexts of aging, elderly users subjectively weigh PV in monetary exchanges and other service dimensions such as reliability, convenience, emotional resonance, and social inclusion [24, 33].

Valarie Zeithaml [34] first proposed that PV is the consumer's overall evaluation of the utility of a service based on perceptions of what is received and what is given [35]. However, for elderly passengers, the perception of value is considered not only in terms of money but also emotional, functional, and social value [36].

In the context of train services, PV represents older adults' perception of the value and worth of their journey experience relative to their expectations and needs. Functional value includes utility, reliability, physical comfort, and access to support services, such as available elevators or the need for staff assistance [37]. Emotional value includes safety, dignity, and enjoyment during travel. In contrast, social value relates to social integration, for example, not having to rely on others to get around or being able to visit family, which in turn may ease feelings of loneliness [38].

Wang et al. [29] stress that PV is the determinant that intervenes between service attributes and their outcomes, for example, innovation or quality, and satisfaction. That means that innovation itself might not be translated into satisfaction without users' perception that the innovation is valuable to them. This notion could apply to the aging population, whose cognitive load and risk perception are projected to influence how innovations could be internalized significantly.

In addition, Norfadhilah Mohd et al. [39] study suggests that PV among the elderly is determined by specific touchpoints, namely the friendliness of staff, information on signs, cost of travel, and the comfort level of waiting areas. The perception of value is further enhanced when physical ability, income level, or social support is restricted, a situation

most older adults find themselves in.

In the specific context of railways and airlines, value-added features (e.g., customizable options for ticketing, quiet zones, and accessible boarding) have been shown to directly impact older passengers' perceptions of the relevancy and suitability of the service [40, 41]. They found this was often a greater predictor of satisfaction than purified service quality, which aligns with value being more of an overarching construct. Hence, PV is a means whereby older users decide on continuance usage and develop a sense of ongoing satisfaction and brand trust, suggesting that perceived value has a mediating role.

H_3: Perceived value (PV) → Passenger service quality (PSQ).

H_4: Perceived value (PV) → Elderly passenger satisfaction (EPS).

2.3. Passenger Service Quality (PSQ)

Passenger service quality (PSQ) is essential in consumer behavior and satisfaction models in service industries like transportation. It is defined as the customer's judgment of the overall quality of a service offer according to the degree to which that service meets or exceeds their expectations [42]. For older train passengers, the evaluation extends beyond the traditional dimensions of service quality, such as on-time performance and station hygiene, to incorporate accessibility, emotional comfort, and responsiveness of service personnel [18, 19, 43].

The well-known SERVQUAL model [42, 44] identified five service quality dimensions derived from several items developed to understand customers' expectations and perceptions of service quality, i.e., tangibility, reliability, responsiveness, assurance, and empathy. Some or all of these elements are particularly important to older adults, who may sometimes rely on the physical environments (such as rails or signage), effective communication, and/or service assistance (such as staff in attendance) to enjoy a safe, independent, and self-esteem-enhancing travel experience [45].

The elderly place a high value on physical comfort (e.g., seat availability, cleanliness, air conditioning), punctuality, the kindness of personnel, and the ability to access passenger information promptly [46] putting, thus, more emphasis on tangible infrastructure and the emotional safety that well-trained service personnel provide.

In addition, service quality is affected by previously perceived value. De Giovanni [47] argues that customers who perceive a greater emotional, social, or economic value from a service will evaluate the quality of that service even more positively, even in the presence of relatively minor service limitations. In the context of the elderly, that means that the more a train service is felt to be 'worthwhile' whether because of affordability, emotional reassurance, or usability the higher it will be evaluated in terms of quality.

Therefore, existing research in the Southeast Asian region demonstrated that among elderly passengers, service quality is not solely technical but also relational that is, empathy, interaction quality, and perceived safety [19]. These elements must be part of any policy/service models that maximize elderly satisfaction.

H_5: Passenger service quality (PSQ) → Elderly passenger satisfaction (EPS)

2.4. Elderly Passenger Satisfaction (EPS)

Customer satisfaction is generally defined as a person's pleasurable fulfillment response resulting from the perceived performance of a service concerning his or her expectations [48]. In public transportation services, especially for railway services, passenger satisfaction is derived from the cumulative evaluations of different service elements e.g., ticket issues, boarding process, physical features within the train, punctuality, and staff behavior [49]. For senior passengers, these service elements lose significance and importance due to physical weaknesses, risk aversion, and the need for security, privacy, and dignity in travel.

Service quality has been identified as an important antecedent to satisfaction in the service industry [50]. In transportation, train passengers are more likely to be satisfied if they perceive services to be performed in a timely, safe, and responsive manner [46]. This is particularly true among older adults, who rely on public transport more frequently, and for whom service success depends upon stability, predictability, and user-centered design [16].

The SERVQUAL model dimensions of tangibility, assurance, reliability, empathy, and responsiveness universally and directly contribute to older passenger satisfaction; however, empathy and reliability are commonly rated as the highest contributors [43]. Older passengers are found to be particularly sensitive to staff treatment, station and coach accessibility, as well as whether their needs (e.g., availability of seats, access to toilet facilities onboard) are anticipated [39].

In addition, Kaewwongwattana et al. [45] documented that service satisfaction among the elderly is inextricably linked to perceptions of dignity and fairness. Views of an inclusive, cousrteous, and reliable transportation system help foster satisfaction and confidence in public institutions. Our findings corroborate an expanding consensus that good service quality is a prerequisite for sustained elderly ridership and the success of transport initiatives over time [46].

2.5. Research Objectives

RO1: To examine the perceptions of EPS toward SI, PV, and PSQ in Thailand's railway system.

RO2: To develop an SEM of factors influencing elderly satisfaction with Thai train services.

RO3: To validate the relationships among service innovation, perceived value, service quality, and elderly passenger satisfaction using empirical data.

2.6. Research Questions

RQ1: How do elderly passengers perceive service innovation in the context of train service delivery?

RQ2: How does service innovation affect perceived value and service quality among elderly railway users?

RQ3: How do perceived value and service quality contribute to overall satisfaction among elderly train passengers?
RQ4: Does service innovation indirectly influence elderly satisfaction through perceived value and service quality?

2.7. Conceptual Model

Figure 2 shows the study's conceptual model.

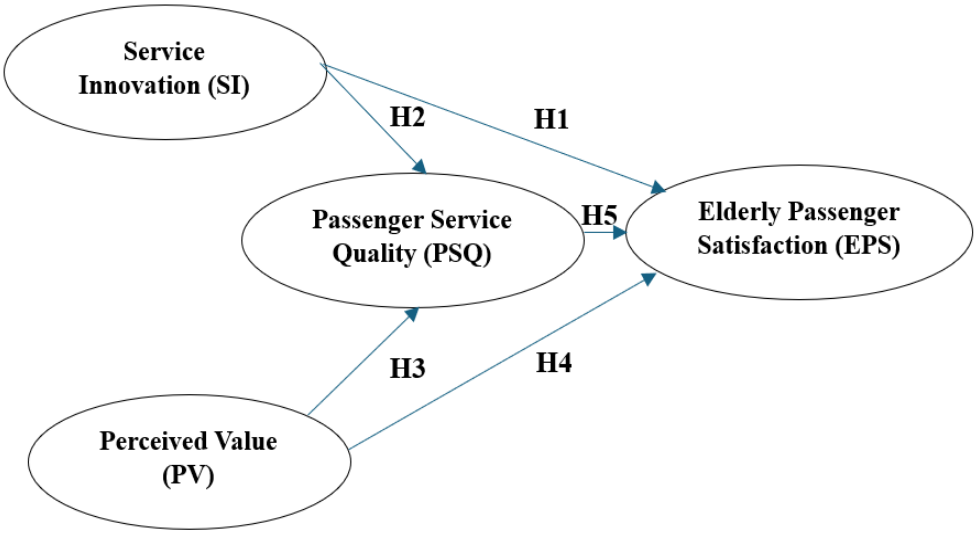

Figure 2.
Conceptual model.

3. Methods

3.1. Population and Sample Determination

The study's sample consisted of elderly SRT passengers who were 60 years old or older and had used SRT rail services more than once. Sample size determination employed commonly accepted SEM criteria, which suggest 20 cases per observed variable for strong statistical evaluation [51]. The study used 17 observed variables; the minimum required sample size was 340. To enhance the SEM model's stability and generalizability, the final population size was increased to 625 samples.

3.1.1. Cluster Random Sampling

Railway stations were taken as the primary sampling units at the first stage. A total of 25 stations were randomly selected from five main SRT lines in Thailand, including the Northern, Northeastern, Eastern, Southern, and Mae Klong lines, with five stations selected per line (Figure 3).

Figure 3.
State Railway of Thailand's rail routes.
Source: https://tinyurl.com/4akc84ua.

3.1.2. Systematic Random Sampling

In the next stage, systematic sampling of elderly passengers was conducted at each station. To accurately capture daily travel patterns in a balanced manner, the surveying periods were divided into five 2-hour time slots: 6:00–8:00, 9:01–11:00, 11:01–13:00, 13:01–15:00, and 15:01–17:00. Within these time slots, five qualified passengers were identified,

resulting in a total of 625 usable cases. These combined stratified samples by line and time were considered to meet adequate distribution and random field selection criteria, thereby reducing potential bias and deviation.

3.1.3. Response Rate

Six hundred fifty questionnaires were distributed, from which 625 complete questionnaires were obtained, indicating that the usable response rate was 96%. The high response rate was attributed to several factors:

- Administration directly by trained researchers at the stations decreases non-response bias
- Locations and time intervals are carefully selected to correspond to high commuter density
- Clear instructions and verbal reassurance of responses being kept confidential are likely to increase trust

Non-monetary motivation was provided in that participants were informed about the social importance of the study, especially its focus on improving mobility for older people and persons with disabilities.

3.2. Data Analysis

The research instrument used for the study consisted of a closed-ended questionnaire, which was subdivided into five sections. These included general information concerning each passenger's gender, age, occupation, status, education level, occupation, monthly income, and the average number of times they rode an SRT train weekly. Part 2 addressed SI factors, Part 3 covered PV factors, and Part 4 contained items concerning PSQ. The final section focused on EPS. Items in Parts 2-5 used a 5-level Likert-type scale assessment. The mean scale, values, and interpretation for the five levels of possible response were: '5' indicating the strongest agreement (4.21 - 5.00), followed by '4' indicating strong agreement (3.41 - 4.20), '3' indicating a moderate or neutral response (2.61 – 3.40), '2' indicating disagreement with the item (1.81 – 2.60), and '1' indicating no agreement with the item or question (1.00 – 1.80) [52, 53].

3.3. Validity and Weight of the Structural Model Indicators

The confirmatory factor analysis (CFA) was used to evaluate the proposed structural equation model's internal structure and measurement efficacy [54]. The results of the CFA, as shown in Table 4, indicated that the model had an excellent fit to the empirical data, with the chi-square being nonsignificant ($\chi^2 = 32.53$, df = 22, p = 0.57). Furthermore, the ratio of chi-square to degrees of freedom ($\chi^2/df = 1.47$) was well below the commonly accepted threshold of 2.00, suggesting a well-fitting model [55]. Groskurth, other indices also supported the model's validity with the RMSEA and RMR indices = 0.00, indicating very little residual error [56]. Finally, the CFI, GFI, and AGFI indices were each 0.99, indicating that the data fit the model nearly perfectly and confirming the measurement model's robustness.

4. Results and Discussion

4.1. Older Passenger Demographics

Table 1 summarizes the demographic profile of the 625 respondents. Females made up a slightly larger share (54.10%) than males (45.90%), consistent with aging and mobility studies showing women's greater reliance on public transport for household and social activities [53]. Most respondents were aged 60–65 (48.64%), followed by 65–70 (33.12%), and 70+ (18.24%), suggesting that the younger elderly group remains more active and independent in travel.

Marital status showed that 57.76% were married, 27.36% were single, and 14.88% were widowed, divorced, or separated. Regarding education, 52.32% had below-bachelor qualifications, 36.96% held bachelor's degrees, and only 10.72% had postgraduate credentials, mirroring national patterns and pointing to historic inequities in lifelong learning access.

Most respondents were retired (81.76%), with the rest distributed across private employment and small businesses. Income levels showed that 54.08% earned between 10,001 and 20,000 ฿, and 30.40% earned between 20,001 and 30,000 ฿. These figures highlight the price sensitivity of this demographic and support the study's focus on perceived value [57].

Regarding travel frequency, 53.92% used the train 1–2 times per week, and 23.04% 3–5 times, confirming its regular, though not daily, role in their lives [58].

These patterns reflect the unique mobility needs and constraints of older adults, particularly low-income retirees. As supported by prior studies [17, 59], affordable, accessible rail transport is essential for the elderly's well-being, independence, and social connection.

Table 1.
Elderly passenger demographics.

Questionnaire Item	Passengers	%
Gender		
Male	284	45.90
Female	338	54.10
Total	625	100
Age		
60-65 years	304	48.64
65-70 years	207	33.12
70 and over	114	18.24
Total	625	100
Relationships		
Single	171	27.36
Married	361	57.76
Divorced/ Widowed/ Separated	93	14.88
Total	625	100
Education		
Less than a bachelor's degree	327	52.32
Bachelor's degree	231	36.96
Master's degree	43	6.88
Doctorate	24	3.84
Total	625	100
Occupation		
Farmer	26	4.16
Self-employed/Trading	24	3.84
Private company employee/Employee	39	6.24
General employee	25	4.00
Retired	511	81.76
Total	625	100
Monthly income		
Less than or equal to 10,000 ฿	70	11.20
10,001-20,000 ฿	338	54.08
20,001-30,000 ฿	190	0.40
30,001-40,000 ฿	19	3.04
40,001-50,000 ฿	5	0.80
Over 50,000 ฿	3	0.48
Total	625	100
Weekly trip frequency		
1-3 trips per week	337	53.92
3-5 trips per week	144	23.04
6-8 trips per week	89	14.24
8-10 trips per week	37	5.92
More than 10 trips per week	18	2.88
Total	625	100

4.2. Descriptive Statistics

The data indicate that elderly respondents generally highly perceived the four primary constructs of SI, PV, PSQ, and EPS (Table 2). Within SI, *customer interface* received the highest rating (mean = 4.32), followed by *creative service ideas* and *technological processes*, supporting the importance of intuitive, human-centered design in elder-focused services [60, 61]. For PV, *price value* scored highest (mean = 4.43), affirming affordability as a key satisfaction driver in this group, consistent with Zeithaml's cost-benefit perspective [35]. Emotional and social value were also rated highly, indicating that trains may offer comfort and social interaction in addition to transportation. In SQ, *reliability* (mean = 4.50) and *responsiveness* (mean = 4.47) were the most influential SERVQUAL factors [61], reflecting the need for dependable service delivery and consistent information flow. EPS findings showed *physical characteristics* (mean = 4.40), sanitation, accessibility, and comfort ranked highest, followed by *convenience* and *employee service*, echoing Herzberg's hygiene factor framework [62]. Overall, value and reliability appear to be the most critical factors for elderly satisfaction, supporting inclusive transit policies that emphasize affordability, predictability, and user-centered design.

Table 2.
Descriptive statistics of core constructs and observed variables.

Construct	Observed Variable	Item	Mean	SD	Interpretation	Skewness	Kurtosis
Service Innovation (SI)	New service delivery	SI1	4.28	0.72	Very High	-3.67	-1.09
	New technology in service	SI2	4.30	0.72	Very High	-3.48	-1.12
	Creative service ideas	SI3 SI4	4.31	0.69	Very High	-4.76	-1.09
	Customer interface	SI1	4.32	0.62	Very High	-5.76	-1.66
Perceived Value (PV)	Functional (use) value	PV1	4.38	0.54	Very High	-3.67	-1.09
	Price value	PV2	4.43	0.48	Very High	-6.13	-1.97
	Emotional value	PV3	4.37	0.48	Very High	-4.97	-1.34
	Social value	PV4	4.34	0.55	Very High	-5.90	-1.10
Passenger Service Quality (PSQ)	Tangibility	PSQ1	4.20	0.45	High	-5.54	-1.33
	Reliability	PSQ2	4.50	0.72	Very High	-3.98	-0.33
	Responsiveness	PSQ3	4.47	0.63	Very High	-4.53	-1.14
	Assurance	PSQ4	4.38	0.55	Very High	-3.65	-0.23
	Empathy	PSQ5	4.14	0.89	High	-5.21	-1.33
Elderly Passenger Satisfaction (EPS)	Physical characteristics	EPS1	4.40	0.89	Very High	-2.53	-0.54
	Convenience	EPS2	4.32	0.84	Very High	-4.76	-1.75
	Employee service	EPS3	4.31	0.72	Very High	-5.35	-1.66
	Service channels	EPS4	4.15	0.89	High	-2.53	-1.74

4.3. Integration of Skewness and Kurtosis Interpretation

In this study, skewness and kurtosis were calculated for each observed variable to assess the distributional characteristics of the data [63]. Skewness values for all items were negative, indicating that responses tended to cluster toward the upper end of the Likert scale (Table 2), reflecting generally favorable attitudes among the elderly respondents, this leftward skew is particularly pronounced in variables such as '*customer interface*' (skewness = -5.76) and '*price value*' (skewness = -6.13), suggesting ceiling effects where participants expressed strong agreement with service attributes.

Similarly, the kurtosis values, which measure the 'peakedness' of the distribution **[64],** were notably high in absolute terms, especially in the range of -3.65 to -6.75. These results imply leptokurtic distributions, meaning the responses are concentrated more tightly around the mean than expected under normal conditions. Such patterns are typical in satisfaction studies where respondents are a self-selecting group of service users with positive experiences or expectations.

While SEM is relatively robust to moderate non-normality, extreme skewness and kurtosis can affect estimation efficiency and the accuracy of fit indices, particularly when using Maximum Likelihood Estimation (MLE) [65]. Nonetheless, the sample size (n = 625) mitigates these concerns to an extent, as larger samples reduce the impact of non-normality through the central limit theorem. Skewness values less than |2| and kurtosis values less than |7| are generally acceptable for SEM using MLE, and all variables in this study fall within or near these thresholds. Therefore, while the distributional characteristics suggest a non-normal response pattern typical of attitudinal data in service research, they are unlikely to threaten the validity of the SEM results in this context.

4.4. Pearson Correlation Coefficient Testing

The SEM was tested to examine the relationships among Thailand's SI [12], PV [47], PSQ, and EPS. Table 3 presents the Pearson correlation coefficients among the four latent variables included in the model.

The results reveal that all six latent variable pairwise correlations were statistically significant at the 0.01 level. The strongest relationship was observed between PV and SI (r = 0.76), followed closely by EPS and PV (r = 0.74). The weakest, although still a significant correlation, was found between PSQ and SI (r = 0.44). Significantly, none of the correlation coefficients exceeded the commonly accepted threshold of 0.80, indicating that multicollinearity was not a concern [66]. This suggests that all latent variables were sufficiently distinct, and their interrelationships fell within acceptable theoretical and statistical bounds.

To further verify the appropriateness of the model for SEM, Bartlett's Test of Sphericity and the Kaiser-Meyer-Olkin (KMO) measure were used to assess the adequacy of the correlation matrix [67]. Bartlett's Test produced a statistically significant result (χ^2 = 393.736, df = 6, p < .001), indicating that the observed correlation matrix differed significantly from an identity matrix (Table 3). Moreover, the KMO value of 0.876 exceeds the recommended minimum threshold of 0.60, confirming the sampling adequacy for factor analysis. These diagnostics affirm that the observed variables are sufficiently interrelated to proceed with SEM. These findings support the theoretical assumption that the constructs are meaningfully connected and distinct, and that the model's structure is appropriate for further examination of causal relationships using SEM.

Table 3.
Correlation coefficient of SEM variables.

Observable variables	Correlation coefficient			
	SI	**PV**	**PSQ**	**EPS**
SI	1.00			
PV	0.76**	1.00		
PSQ	0.44**	0.69**	1.00	
EPS	0.72**	0.74**	0.50**	1.00
KMO: Measure of Sampling Adequacy = 0.876, Bartlett's Test of Sphericity: Chi-Square= 393.736, df = 6, p = 0.00				

Note: **Sig.< .01.

4.5. Model Fit and Measurement Loadings

Table 4 presents the standardized factor loadings, t-values, and coefficients of determination (R^2) for the observed variables associated with each latent construct in the structural equation model. The results confirm the reliability and convergent validity of the measurement model. All factor loadings are statistically significant at the $p < .01$ level, ranging from 0.78 to 0.87, indicating strong associations between the latent variables, SI, PV, PSQ, and EPS, and their corresponding indicators. The coefficients of determination (R^2), which reflect the proportion of variance in each observed variable explained by its latent construct, range from 0.31 to 0.37, suggesting a satisfactory level of explanatory power [68].

Several loadings (e.g., PSQ1 and EPS1) were specified with constrained parameters; therefore, standard errors and t-values were not estimated for those indicators. Nevertheless, the magnitude of the component weights remains within the acceptable threshold, affirming the constructs' internal consistency. Moreover, the overall model fit statistics support the adequacy of the measurement model, with $\chi^2 = 32.53$, df = 22, p = 0.57, $\chi^2/df = 1.47$, RMSEA = 0.00, RMR = 0.00, CFI = 0.99, GFI = 0.99, and AGFI = 0.99. These values exceed conventional fit criteria, indicating that the model fits the empirical data exceptionally well and validates the structure of latent constructs in capturing elderly passengers' perceptions of train service quality and their resulting loyalty behaviors.

Table 4.
Factor loadings and coefficients of determination (R^2).

Latent variables	Observed variables	Component weight			
		b_{sc}	**SE**	**t**	**Coefficients of determination (R^2)**
SI	SI1	0.78**	0.06	14.23	0.31
	SI2	0.83**	0.06	15.25	0.35
	SI3	0.84**	0.05	15.43	0.35
	SI4	0.87**	0.05	15.86	0.37
PV	PV1	0.84**	0.06	15.26	0.35
	PV2	0.85**	0.06	15.63	0.36
	PV3	0.84**	0.06	15.38	0.35
	PV4	0.86**	0.05	15.89	0.37
PSQ	PSQ1	0.84**	<-->	<-->	0.35
	PSQ2	0.85**	0.07	12.53	0.36
	PSQ3	0.86**	0.07	12.70	0.37
	PSQ4	0.85**	0.07	12.60	0.36
	PSQ5	0.85**	0.07	12.56	0.36
EPS	EPS1	0.84**	<-->	<-->	0.35
	EPS2	0.83**	0.07	12.23	0.34
	EPS3	0.80**	0.07	11.94	0.32
	EPS4	0.82**	0.07	12.10	0.33

Note: **p < .01; bsc = standardized component weights; dashes <--> indicate constrained parameters where SE and t-values were not estimated. Chi-Square = 32.53, df = 22, p = 0.57, χ^2/ df = 1.47, RMSER = 0.00, RMR = 0.00, CFI = 0.99, GFI = 0.99, AGFI = 0.99.

4.6. Analysis of Total, Direct, and Indirect Effects on Elderly Passenger Satisfaction (EPS)

The structural path analysis examined the causal influences of the three key exogenous variables, passenger service quality (PSQ), service innovation (SI), and perceived value (PV), on the endogenous outcome variable, elderly passenger satisfaction (EPS), among elderly railway users.

Collectively, these predictors accounted for 74% of the variance in elderly customer satisfaction ($R^2 = 0.74$), demonstrating strong explanatory power. When considering total effects, service quality exerted the most significant influence on satisfaction (TE = 0.94), followed closely by service innovation (TE = 0.93), with perceived value (TE = 0.65) ranking third. These results underscore the central role of service quality in shaping user satisfaction, highlighting the substantial contributions of innovation and value perception.

In terms of direct effects, all three variables significantly impacted satisfaction at the 0.01 level, with PSQ having the most substantial direct effect (DE = 0.94), followed by service innovation (DE = 0.68) and perceived value (DE = 0.42).

These findings reinforce the theoretical hierarchy of influence in which operational performance and service delivery processes weigh most heavily on user evaluations.

The model also revealed significant indirect effects, with service innovation (IE = 0.25) and perceived value (IE = 0.23) influencing satisfaction indirectly through service quality. These mediated effects suggest that enhancements in service innovation and value perception contribute to satisfaction through their direct pathways and by improving the perceived quality of service delivery [69].

These results demonstrate a well-balanced and statistically coherent model in which all paths are conceptually meaningful and empirically supported. They confirm that improving service quality remains the most immediate and effective route to enhancing satisfaction among elderly train users. However, innovation and perceived value are complementary levers that reinforce this outcome, directly and through interrelated mechanisms.

Table 5.
Direct effects (DE), indirect effects (IE), and total effects.

Outcome variable	R^2	Effect	Causal variable		
			PSQ	PV	SI
PSQ	0.54	DE	-	0.46**	0.65**
		IE	-	-	-
		TE	-	0.46**	0.65**
EPS	0.74	DE	0.94**	0.42**	0.68**
		IE	-	0.23**	0.25**
		TE	0.94**	0.65**	0.93**

Note: **$p < .01$; – no parameter line according to the research hypothesis.

4.7. Results of the Structural Model Analysis

The results, shown in Table 6 and illustrated in Figure 4, indicate that all three independent variables exert statistically significant and positive influences on elderly passenger satisfaction, confirming the hypothesized model relationships.

Table 6.
Final hypothesis testing.

Hypotheses statements	Coef.	t-test	Test results
H1: Service innovation (SI) → Elderly passenger satisfaction (EPS)	0.68	14.23**	Consistent with the research hypothesis
H2: Service innovation (SI) → Passenger service quality (PSQ)	0.65	13.74**	Consistent with the research hypothesis
H3: Perceived value (PV) → Passenger service quality (PSQ)	0.46	12.38**	Consistent with the research hypothesis
H4: Perceived value (PV) → Elderly passenger satisfaction (EPS)	0.42	10.36**	Consistent with the research hypothesis
H5: Passenger service quality (PSQ) → Elderly passenger satisfaction (EPS)	0.94	15.44**	Consistent with the research hypothesis

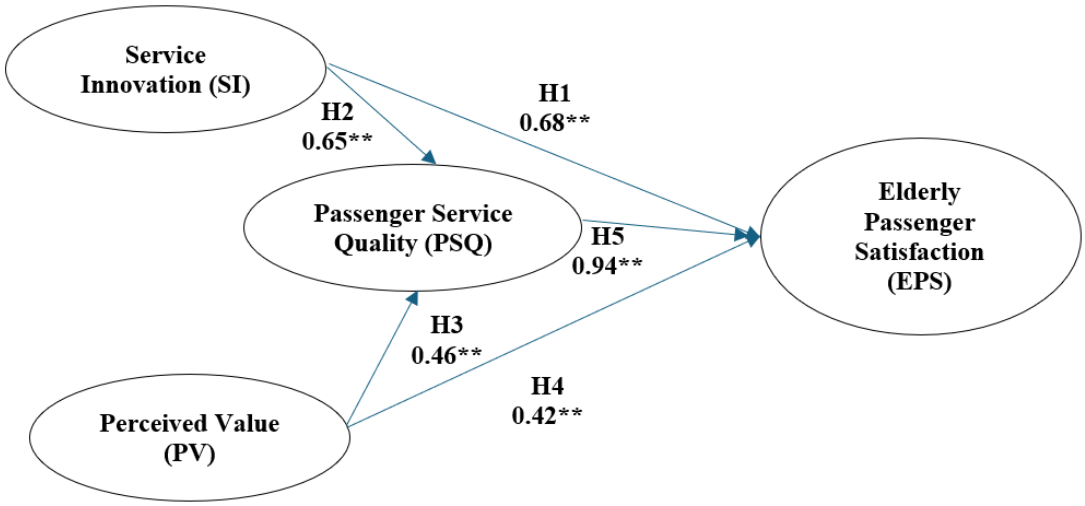

Figure 4.
SEM final model.
Note: Chi-Square = 32.53, df = 22, p = 0.57, χ^2/ df = 1.47, RMSER = 0.00, RMR = 0.00, CFI = 0.99, GFI = 0.99, AGFI = 0.99.

5. Conclusions

The findings of this study provide practical and academic insights into how SI, PV, and PSQ influence EPS in Thailand. The SEM explained 74% of the variance in EPS, confirming the relationships' theoretical assumptions and empirical strength.

Passenger service quality emerged as the most influential factor, with a total effect of 0.94 on satisfaction. This supports prior studies, such as those by Ikani and Ikani [70], who found that PSQ significantly shaped satisfaction across rail and bus transport contexts. In this study, PSQ included tangible and process-oriented *service* attributes like reliability, responsiveness, and staff competence. Therefore, railway management must prioritize concrete and visible service delivery improvements. This includes investing in professional, knowledgeable, and courteous staff while improving responsiveness to passenger needs.

Service innovation followed closely (TE = 0.93), indicating its decisive role in enhancing customer experience. Innovations in digital platforms, mobile responsiveness, and new delivery mechanisms are particularly relevant to older passengers, whose needs often require more transparent communication and better user interfaces [31, 65]. Management should embrace multi-channel service innovations, especially app-based platforms allowing real-time assistance and feedback without time or location constraints. Such innovations are not merely technological upgrades but are competitive differentiators in today's digital landscape.

Perceived value, though ranked third (TE = 0.65), remains an essential construct, as elderly passengers assess value through price and emotional and social dimensions of the travel experience. Increasing comfort, safety, and social engagement during train journeys can significantly improve these perceptions [19]. As the elderly demographic often associates value with well-being and dignity, service design should reflect these expectations.

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