





# “From service and facility quality to loyalty in urban tourism: Mediating role of visitor satisfaction in Jakarta’s public parks”

<b>AUTHORS</b>	Suwandi Arjuna Wiwaha  Junaid Ali Saeed Rana  
<b>ARTICLE INFO</b>	Suwandi, Arjuna Wiwaha and Junaid Ali Saeed Rana (2025). From service and facility quality to loyalty in urban tourism: Mediating role of visitor satisfaction in Jakarta’s public parks. <i>Tourism and Travelling</i> , 5(1), 1-13. doi: <a href="https://doi.org/10.21511/tt.5(1).2026.01">10.21511/tt.5(1).2026.01</a>
<b>DOI</b>	<a href="http://dx.doi.org/10.21511/tt.5(1).2026.01">http://dx.doi.org/10.21511/tt.5(1).2026.01</a>
<b>RELEASED ON</b>	Tuesday, 07 April 2026
<b>RECEIVED ON</b>	Sunday, 22 February 2026
<b>ACCEPTED ON</b>	Wednesday, 01 April 2026
<b>LICENSE</b>	 This work is licensed under a <a href="https://creativecommons.org/licenses/by/4.0/">Creative Commons Attribution 4.0 International License</a>
<b>JOURNAL</b>	"Tourism and Travelling"
<b>ISSN PRINT</b>	2544-2295
<b>ISSN ONLINE</b>	2616-5090
<b>PUBLISHER</b>	LLC “Consulting Publishing Company “Business Perspectives”
<b>FOUNDER</b>	Sp. z o.o. Kozmenko Science Publishing



NUMBER OF REFERENCES

46



NUMBER OF FIGURES

2



NUMBER OF TABLES

8

© The author(s) 2026. This publication is an open access article.



## BUSINESS PERSPECTIVES



LLC “CPC “Business Perspectives”  
Hryhorii Skovoroda lane, 10,  
Sumy, 40022, Ukraine  
[www.businessperspectives.org](http://www.businessperspectives.org)

**Type of the article:** Research Article

**Received on:** 22<sup>nd</sup> of February, 2026

**Accepted on:** 1<sup>st</sup> of April, 2026

**Published on:** 7<sup>th</sup> of April, 2026

© Suwandi, Arjuna Wiwaha, Junaid Ali Saeed Rana, 2026

Suwandi, Bachelor Student, School of Management, Faculty of Economics and Business, University of Jakarta International, Indonesia.

Arjuna Wiwaha, Associate Professor, Vice Rector for Academic Affairs and Students, Faculty of Economics and Business, University of Jakarta International, Indonesia.

Junaid Ali Saeed Rana, Ph.D., Assistant Professor, Dean, Faculty of Economics and Business, University of Jakarta International, Indonesia. (Corresponding author)



This is an Open Access article, distributed under the terms of the [Creative Commons Attribution 4.0 International license](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted re-use, distribution, and reproduction in any medium, provided the original work is properly cited.

**Conflict of interest statement:**

Author(s) reported no conflict of interest

Suwandi (Indonesia), Arjuna Wiwaha (Indonesia), Junaid Ali Saeed Rana (Indonesia)

# FROM SERVICE AND FACILITY QUALITY TO LOYALTY IN URBAN TOURISM: MEDIATING ROLE OF VISITOR SATISFACTION IN JAKARTA’S PUBLIC PARKS

## Abstract

Urban public parks are increasingly recognized as important components of sustainable and green urban tourism systems, contributing to destination attractiveness, environmental quality, and visitor well-being. However, limited research explains how the quality of park facilities and services influences visitor behavior within urban tourism markets in emerging megacities. Grounded in the quality–satisfaction–loyalty framework, this study examines the effects of facility quality and service quality on visitor satisfaction and visitor loyalty across Jakarta’s public parks. Using 307 valid responses analyzed via partial least squares structural equation modeling (PLS-SEM), the findings reveal that both quality dimensions significantly enhance visitor satisfaction, which, in turn, strongly drives loyalty. Visitor satisfaction mediates the relationship between quality dimensions and visitor loyalty, with full mediation observed for facility quality and partial mediation for service quality, underscoring its central role in shaping repeat visitation and positive word-of-mouth in urban green tourism contexts. The study contributes to the literature on tourism marketing and sustainable destination management and offers practical implications for tourism authorities and park managers seeking to strengthen satisfaction-driven loyalty in urban tourism markets.

## Keywords

facility quality, service quality, visitor satisfaction, visitor loyalty, sustainable urban tourism, urban tourism, public parks

## JEL Classification

L83, M31, Z32, R11

## INTRODUCTION

Rapid urbanization in the 21<sup>st</sup> century has intensified pressures on urban ecosystems and the quality of life in global megacities. Understanding how residents and tourists engage with urban tourism spaces has become essential for sustainable tourism development and destination competitiveness. Public green spaces serve as critical urban tourism infrastructure, supporting environmental resilience, community well-being, and visitor experience. Beyond ecological functions such as flood mitigation and air purification, urban parks provide recreational, social, and psychological benefits that enhance destination attractiveness and urban liveability.

In Jakarta, Indonesia’s capital and a megacity of over ten million residents, the revitalization of urban parks has emerged as a key strategy for strengthening the city’s competitiveness within urban tourism markets. Major initiatives such as Tebet Eco Park (TEP), alongside community-oriented parks like Taman Sungai Kendal and Taman Cattleya, reflect efforts to improve urban leisure environments and visitor engagement. However, the long-term success of these investments depends not only on physical and service improvements but

also on fostering sustained visitor satisfaction and loyalty, which drive repeat visitation, positive word-of-mouth, and broader tourism market performance.

This study is grounded in the quality–satisfaction–loyalty (Q-S-L) framework (Oliver, 1980), which posits that perceived quality influences satisfaction, which, in turn, drives loyalty. In urban tourism contexts, quality encompasses both facility quality, including tangible attributes such as infrastructure, cleanliness, safety, and accessibility, and service quality, reflecting intangible elements such as responsiveness, empathy, and management effectiveness. Empirical evidence across tourism and hospitality settings confirms these relationships (Hussain et al., 2023; Gajić et al., 2023), while studies in broader service contexts also highlight satisfaction as a key mediating mechanism (Shah et al., 2024; Baba, 2018). Tourism research similarly emphasizes that visitor satisfaction plays a central role in shaping behavioral loyalty in tourism destinations, including protected natural environments (Carvache-Franco et al., 2020). Additional studies demonstrate that facility and service quality significantly influence satisfaction and loyalty outcomes in tourism settings (Umul et al., 2023; Pangestu et al., 2023; Andayani et al., 2021; Vu, 2021).

Despite the robustness of the Q-S-L framework, its application to publicly managed urban tourism spaces remains limited, particularly in emerging urban tourism markets in Southeast Asia. Most prior research has focused on commercial tourism environments, overlooking how quality perceptions and satisfaction operate in non-transactional public spaces (Dharmawan & Sitio, 2020; Nursyamsiah & Setiawan, 2023; Santoso et al., 2025). Urban parks function as spatially embedded tourism resources, with accessibility and integration into urban mobility patterns shaping visitor experience and engagement. However, empirical evidence remains limited regarding how perceived quality translates into sustained visitor loyalty in publicly managed urban tourism environments. Bibliometric studies further confirm the underrepresentation of research on urban green tourism satisfaction and loyalty in the Asia-Pacific region (Zhang et al., 2025).

---

## 1. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

From a tourism management perspective, visitor satisfaction and loyalty are fundamental indicators of destination competitiveness and sustainable tourism development. Urban parks function as important urban tourism destinations where physical infrastructure and service delivery shape visitor experience and behavioral outcomes. This study is grounded in the quality–satisfaction–loyalty (Q-S-L) paradigm (Oliver, 1980), which posits that perceived quality influences satisfaction, which in turn fosters loyalty. This paradigm is complemented by the service quality model (Parasuraman et al., 1988), which distinguishes between tangible and intangible quality dimensions, and the attitude–behavior framework (Ajzen, 1991), which explains how satisfaction translates into behavioral loyalty. Expectancy–disconfirmation theory further explains that satisfaction arises

when perceived performance meets or exceeds expectations (Oliver, 1980). Environmental psychology and servicescape research also demonstrate that well-designed and well-managed physical environments promote positive emotional responses and repeated use (Bitner, 1992; Gehl, 2011; R. Kaplan & S. Kaplan, 1989). Empirical studies confirm that both tangible and intangible quality dimensions are essential for sustaining visitor engagement and shaping perceptions of park quality (Zhao et al., 2025; Shao & Chung, 2024; Felappi et al., 2024).

In the context of urban parks, perceived quality comprises two key dimensions: facility quality (FQ), which represents the physical environment, and service quality (SQ), which represents management and service delivery. Visitor satisfaction (VS) serves as the psychological mechanism that links these quality perceptions to visitor loyalty (VL), which reflects both behavioral and attitudinal commitment among users of Jakarta’s revitalized public green spaces.

### 1.1. Facility quality (FQ)

Facility quality refers to the physical attributes and functionality of park infrastructure, including amenities such as seating, restrooms, playgrounds, pathways, lighting, accessibility, and cleanliness. High-quality facilities enhance perceptions of safety, comfort, and convenience, encouraging recreational activity, social interaction, and repeated visitation (Gehl, 2011; Giles-Corti et al., 2005; R. Kaplan & S. Kaplan, 1989). From a tourism perspective, facility quality directly contributes to destination attractiveness and the overall visitor experience. Empirical evidence consistently identifies facility quality as a strong predictor of visitor satisfaction and loyalty, with physical deficiencies negatively affecting visitor perceptions and engagement (Chemeda et al., 2025; Shao & Chung, 2024; Felappi et al., 2024).

Studies in Southeast Asian public spaces further confirm that infrastructure quality significantly influences visitor satisfaction. Suminar et al. (2024) found that infrastructure and service performance jointly shape satisfaction in waterfront public environments, while Nasution et al. (2025) demonstrated similar effects in urban parks. Samsudin and Suhalya (2025) also showed that effective management of public infrastructure enhances user satisfaction across service contexts. These findings suggest that high-quality facilities provide the structural foundation for positive visitor experiences and satisfaction.

### 1.2. Service quality (SQ)

Service quality reflects visitors' evaluation of park management and service delivery, including staff responsiveness, professionalism, empathy, communication, and maintenance effectiveness. The SERVQUAL and SERVPERF frameworks conceptualize service quality as a multidimensional construct encompassing reliability, responsiveness, assurance, empathy, and tangibility (Parasuraman et al., 1988; Cronin & Taylor, 1992; Pakurár et al., 2019). In urban parks, high-quality service enhances visitors' comfort, trust, and emotional connection, contributing to positive perceptions of the destination (Garín-Muñoz & Moral, 2017; Luo & Li, 2024; Akroush et al., 2016).

Empirical studies confirm that service quality plays a critical role in shaping visitor satisfaction and behavioral intentions. Luo and Li (2024) found that service quality significantly influences sustainable visit intentions in park environments, while Nasution et al. (2025) reported that service quality, together with facility quality, strongly predicts satisfaction in urban parks. These findings demonstrate that service delivery complements physical infrastructure by enhancing the overall experiential quality of tourism environments.

### 1.3. Visitor satisfaction (VS)

Visitor satisfaction represents the overall evaluation of visitor experience based on the comparison between expectations and perceived performance (Oliver, 1980; Kotler & Keller, 2016). It integrates both functional and emotional aspects of the visit, reflecting perceptions of facilities, services, and environmental conditions. Within the Q-S-L paradigm, satisfaction serves as the key mediator that converts quality perceptions into behavioral loyalty.

Empirical research consistently demonstrates that satisfied visitors are more likely to revisit destinations, recommend them to others, and develop long-term attachment (Chemeda et al., 2025; Shao & Chung, 2024; Praharjo, 2020). Measurement approaches such as the UParQUAL scale highlight the importance of integrating facility and service dimensions when assessing satisfaction in park environments (Jaafar & Tudin, 2010). Alamas et al. (2024) further showed that satisfaction in park settings depends on both infrastructure and experiential design elements. Tourism geography research also confirms satisfaction as a key determinant of loyalty in park-based tourism destinations (Carvache-Franco et al., 2020).

### 1.4. Visitor loyalty (VL)

Visitor loyalty refers to the visitor's commitment to revisit a destination and recommend it to others, reflecting both behavioral and attitudinal loyalty (Oliver, 1999; Kotler & Keller, 2016). In urban park contexts, loyalty indicates sustained visitor engagement and long-term destination attractiveness. Empirical studies confirm that perceived quality and satisfaction jointly influence loyalty in

park and tourism settings (Garín-Muñoz & Moral, 2017; Luo & Li, 2024; Praharjo, 2020). Research in park environments also demonstrates that satisfaction with facilities and overall experience significantly influences revisit intentions and advocacy behavior (Du & Zhao, 2022; Zhang et al., 2025). These findings highlight the importance of satisfaction as the primary mechanism linking quality perceptions to loyalty outcomes.

### 1.5. Mediating role of visitor satisfaction

The Q-S-L paradigm suggests that facility quality and service quality influence visitor loyalty indirectly through visitor satisfaction. Improvements in facility quality enhance the visitor experience and satisfaction, which in turn strengthen loyalty (Zeithaml et al., 1996; Shao & Chung, 2024). Similarly, service quality contributes to loyalty primarily through satisfaction-driven emotional and cognitive responses (Oliver, 1980; Garín-Muñoz & Moral, 2017; Kaulu et al., 2025).

### 1.6. Conceptual framework and aim

This study aims to examine how facility quality and service quality influence visitor satisfaction and, in turn, visitor loyalty in Jakarta’s urban parks. By empirically testing the mediating role of satisfaction in a publicly managed urban tourism context, the study contributes to tourism marketing and sustainable destination management literature, extends the Q-S-L framework to urban green tourism environments, and provides evidence to inform tourism planning and park management strategies in emerging megacities.

Accordingly, the following hypotheses are proposed:

*H<sub>1</sub>: Facility quality has a significant positive effect on visitor satisfaction.*

*H<sub>2</sub>: Service quality has a significant positive effect on visitor satisfaction.*

*H<sub>3</sub>: Visitor satisfaction has a significant positive effect on visitor loyalty.*

*H<sub>4</sub>: Facility quality has a significant positive indirect effect on visitor loyalty through visitor satisfaction.*

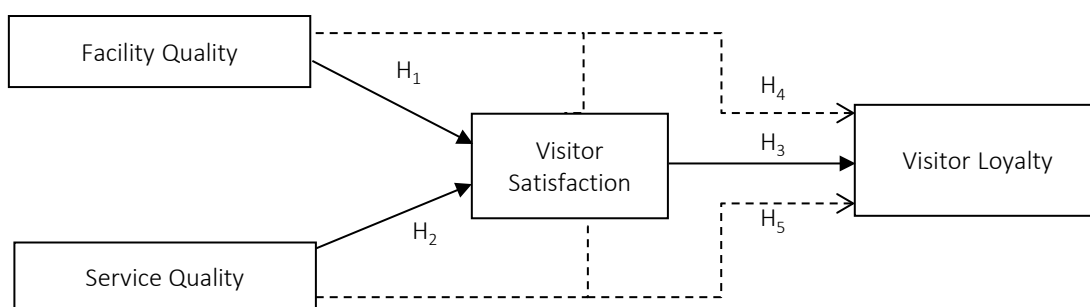
*H<sub>5</sub>: Service quality has a significant positive indirect effect on visitor loyalty through visitor satisfaction.*

The conceptual framework (Figure 1) integrates facility quality and service quality as key determinants of visitor satisfaction, which in turn influences visitor loyalty. This mediation model extends the Q-S-L paradigm beyond commercial tourism environments to publicly managed urban parks, highlighting how physical and service quality jointly shape visitor satisfaction and loyalty in urban tourism destinations. By positioning satisfaction as the central mediating mechanism, the model provides theoretical and empirical insight into how quality perceptions contribute to sustained visitor engagement in megacity tourism environments.

## 2. METHODS

### 2.1. Study area and sampling

Data were collected from visitors to Jakarta’s revitalized public green spaces, which serve as key urban tourism destinations for recreation, social



**Figure 1.** Conceptual model

**Table 1.** Demographic and visitation characteristics of respondents

Characteristic	Category	Tebet Eco Park	Taman Sungai Kendal	Taman Cattleya	Other Parks	Total	
Gender	Male	46	39	29	38	152	49.5%
	Female	54	73	20	8	155	50.4%
Subtotal		100	112	49	46	307	100%
Age	< 18 years	12	18	7	10	47	15.3%
	18-25 years	38	26	13	10	87	28.3%
	26-35 years	12	35	9	10	66	21.5%
	36-45 years	13	17	11	18	59	19.2%
	> 45 years	13	16	9	10	48	15.6%
Subtotal		88	112	49	58	307	100%
Education	Junior High	3	17	4	6	30	9.8%
	Senior High	61	75	33	33	202	65.8%
	Diploma	4	6	4	5	19	6.2%
	Bachelor's	20	14	17	2	53	17.3%
	Postgraduate	0	0	0	3	3	1.0%
Subtotal		88	112	58	49	307	100%
Visit Frequency	First time	22	18	8	10	58	18.9%
	Once a month	17	20	8	29	74	24.1%
	2-3 times/month	20	39	10	24	93	30.3%
	Once a week	11	20	5	7	43	14.0%
	> 1 time/week	18	15	1	5	39	12.7%
Subtotal		88	112	32	75	307	100%
Visit Purpose	Relaxation	<b>29</b>	<b>37</b>	<b>21</b>	<b>10</b>	<b>97</b>	<b>29.94%</b>
	Exercise	<b>31</b>	<b>26</b>	<b>7</b>	<b>22</b>	<b>86</b>	<b>26.54%</b>
	Playing with children	<b>11</b>	<b>38</b>	<b>9</b>	<b>14</b>	<b>72</b>	<b>22.22%</b>
	Family/friends	<b>7</b>	<b>4</b>	<b>5</b>	<b>10</b>	<b>26</b>	<b>8.02%</b>
	Photography/ social media	<b>2</b>	<b>3</b>	<b>1</b>	<b>3</b>	<b>9</b>	<b>2.78%</b>
	Others	<b>8</b>	<b>4</b>	<b>6</b>	<b>16</b>	<b>34</b>	<b>10.49%</b>
Subtotal		<b>88</b>	<b>112</b>	<b>49</b>	<b>75</b>	<b>324</b>	<b>100%</b>

Note: "Other Parks" include Taman Puring, Taman Lapangan Banteng, Taman Malaka Asri, and others. Data were cleaned from an initial 350 responses by removing cases with a standard deviation below 0.25. Respondents were allowed to select more than one visit purpose. Therefore, the total number of responses (324) exceeds the number of valid respondents (307).

interaction, and leisure. Three parks were deliberately selected to represent diverse typologies: Tebet Eco Park (a flagship 7.3-ha sustainable project), Taman Sungai Kendal, and Taman Cattleya (community-oriented with high accessibility). An "other parks" category (e.g., Taman Puring, Taman Lapangan Banteng) ensured broader coverage.

A stratified random sampling approach was used on-site to balance demographics (age, gender, visitation frequency) and capture immediate perceptions. Of 350 initial responses, data screening removed incomplete or low-variance cases (standard deviation < 0.25 on Likert items), yielding 307 valid responses for analysis.

Table 1 summarizes respondent characteristics. The sample was gender-balanced (49.5% male, 50.5% female), predominantly aged 18-25 (28.3%) with senior high education (65.8%).

Most visited 2–3 times/month (30.3%), primarily for relaxation (31.6%) or exercise (28.0%). Tebet Eco Park and Taman Sungai Kendal were most frequently visited.

## 2.2. Measurement instruments

Constructs were measured with reflective indicators on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree), adapted from validated sources for Jakarta's urban park context.

Facility quality (FQ) included 13 items on amenities, accessibility, cleanliness, comfort, safety, and sustainability (Suminar et al., 2024; Nasution et al., 2025; Samsudin & Suhalya, 2025);  $\alpha = 0.958$ , CR = 0.963, AVE = 0.666. Service quality (SQ) included 7 items on responsiveness, friendliness, professionalism, empathy, and reliability from SERVQUAL/SERVPERF frameworks

(Parasuraman et al., 1988; Cronin & Taylor, 1992; Pakurár et al., 2019; Garín-Muñoz & Moral, 2017; Luo & Li, 2024);  $\alpha = 0.951$ , CR = 0.960, AVE = 0.776. Visitor satisfaction (VS) included 6 items on overall experience and expectation congruence (Alamasi et al., 2024; Jaafar & Tudin, 2010);  $\alpha = 0.959$ , CR = 0.967, AVE = 0.831. Visitor loyalty (VL) included 5 items on revisit intention, word-of-mouth, and recommendation (Du & Zhao, 2022; Zhang et al., 2025);  $\alpha = 0.939$ , CR = 0.954, AVE = 0.805. With 31 indicators and 307 cases, the sample exceeds PLS-SEM guidelines (e.g., the 10-times rule; Chin, 1998; Hair et al., 2017), thereby ensuring model stability.

### 2.3. Data analysis

Analysis used SmartPLS 4.0, suitable for non-normal data, mediation testing, and predictive models in tourism research (Chin, 1998; Hair et al., 2017, 2019). The two-step approach assessed: (1) measurement model (reliability, validity); (2) structural model (path coefficients, mediation).

### 2.4. Ethical considerations

Participation was voluntary with informed consent. No identifiable data were collected; responses remained anonymous and confidential, complying with institutional and national ethical standards.

## 3. RESULTS

### 3.1. Measurement model assessment

Internal consistency reliability was strong: Cronbach’s Alpha (CA) and Composite Reliability (CR) exceeded 0.70 for all constructs (Table 2). Convergent validity was adequate, with Average Variance Extracted (AVE) > 0.50 across constructs (FQ: 0.666; SQ: 0.776; VL: 0.805; VS: 0.831).

**Table 2.** Construct reliability and convergent validity

Construct	Cronbach’s Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
FQ	0.958	0.960	0.963	0.666
SQ	0.951	0.953	0.960	0.776
VL	0.939	0.942	0.954	0.805
VS	0.959	0.959	0.967	0.831

Discriminant validity was confirmed via the Fornell–Larcker criterion (square roots of AVEs exceeded inter-construct correlations; Table 3) and HTMT ratios (all < 0.95 threshold; Table 4), though some values (e.g., SQ – VS = 0.93; VL – VS = 0.924) approached the conservative 0.90 limit due to theoretical relatedness (Hair et al., 2021; Henseler et al., 2015).

**Table 3.** Fornell-Larcker criterion

Constructs	FQ	SQ	VL	VS
FQ	0.816			
SQ	0.859	0.881		
VL	0.779	0.819	0.897	
VS	0.859	0.889	0.879	0.911

**Table 4.** Heterotrait-monotrait (HTMT) ratios

Constructs	FQ	SQ	VL	VS
FQ				
SQ	0.9			
VL	0.818	0.865		
VS	0.895	0.93	0.924	

Indicator reliability and multicollinearity were satisfactory: All standardized loadings > 0.70 (Hair et al., 2017); most VIF < 5.0 (few < 6.0, acceptable for complex models; Hair et al., 2021; Table 5). The questionnaire was developed in Bahasa Indonesia, back-translated by a professional translator, and pilot-tested for clarity and cultural fit. Overall, the measurement model met all criteria for reliability, convergent validity, discriminant validity, and absence of serious multicollinearity.

All indicator loadings were above the recommended threshold of 0.70 (Hair et al., 2017), indicating satisfactory reliability for all constructs. Overall, the measurement model met the essential requirements for reliability, convergent validity, and discriminant validity, confirming that the constructs were appropriately defined and suitable for testing the proposed structural relationships.

**Table 5.** Indicators, factor loadings, and VIF values

Indicator	Item Description (English Translation)	Loading	VIF
<b>Facility Quality (FQ)</b>			
FQ1	Public facilities such as toilets, trash bins, and seating are adequately available	0.814	2.707
FQ2	Facilities such as benches, information boards, and play areas are complete	0.815	2.971
FQ3	Park facilities are kept clean and well-maintained	0.819	3.278
FQ4	The facilities are in good and serviceable condition	0.821	3.393
FQ5	The park location is easily accessible from various directions	0.766	2.680
FQ6	Facilities are accessible to persons with disabilities	0.822	3.292
FQ7	I feel comfortable when using the facilities in this park	0.874	3.628
FQ8	Park facilities are safe for all visitors to use	0.870	3.663
FQ9	The pedestrian paths are comfortable and sufficient	0.823	3.121
FQ10	Parking areas are adequate for the number of visitors	0.705	2.192
FQ11	Supporting facilities such as shaded areas and lactation rooms are available	0.768	2.237
FQ12	Park facilities are designed with environmental and sustainability principles	0.857	3.964
FQ13	The park has a strong physical and aesthetic appeal	0.841	3.718
<b>Service Quality (SQ)</b>			
SQ1	Park staff quickly respond to visitors' needs or questions	0.890	4.007
SQ2	Information such as maps, activity schedules, or directions is clearly available	0.784	2.141
SQ3	Park staff are friendly and polite	0.879	3.653
SQ4	Park staff are knowledgeable enough to answer visitors' questions	0.932	5.741
SQ5	Park staff treat every visitor with equal attention	0.919	5.777
SQ6	The quality of service provided by park staff is consistent	0.909	5.244
SQ7	I do not experience long queues or slow service	0.843	2.800
<b>Visitor Loyalty (VL)</b>			
CL1	I often tell others positive things about this park	0.885	3.103
CL2	I plan to visit this park again in the future	0.918	4.401
CL3	I would recommend this park to friends or family	0.908	4.050
CL4	This park leaves a positive impression on me	0.913	3.904
CL5	I would visit this park even if there were another park closer to me	0.861	2.831
<b>Visitor Satisfaction (VS)</b>			
CS1	I am satisfied with the facilities available in this park	0.910	4.464
CS2	I am satisfied with the services provided by the park staff	0.891	3.544
CS3	I feel comfortable overall during my visit to this park	0.918	4.507
CS4	I feel safe while visiting this park	0.923	4.703
CS5	I have had a positive experience during my visit	0.895	3.981
CS6	The facilities and services meet my expectations	0.931	5.364

### 3.2. Structural model assessment

Collinearity diagnostics showed internal VIF values of 3.813–5.701 (generally < 5.0; some slightly higher but < 10.0, acceptable given conceptual relatedness; Hair et al., 2017; Diamantopoulos & Siguaw, 2006; Table 6).

**Table 6.** Collinearity statistics (VIF)

Constructs	VL	VS
FQ	4.567	3.813
SQ	5.701	3.813
VS	5.693	–

The model demonstrated strong explanatory power:  $R^2 = 0.824$  for VS and  $0.780$  for VL (both > 0.50;

Hair et al., 2019). Predictive relevance was high ( $Q^2 = 0.680$  for VS;  $0.618$  for VL). Effect sizes ( $f^2$ ) indicated small-to-large effects (Table 7), with service quality exerting a strong effect on visitor satisfaction and visitor satisfaction showing a substantial effect on visitor loyalty, while the direct effects of facility quality and service quality on visitor loyalty were negligible and small, respectively.

Having established the model's explanatory and predictive adequacy, the next step examines the significance and strength of the hypothesized relationships among constructs using path coefficients and bootstrapped t-values.

Bootstrapping (5,000 resamples, one-tailed  $p < 0.05$ ) tested hypotheses (Figure 2; Table 8). FQ

**Table 7.** Explanatory strength, effect size, and predictive relevance of the structural model

Endogenous variable	Predictor(s)	R <sup>2</sup>	Q <sup>2</sup>	f <sup>2</sup>	Effect size interpretation
Visitor Satisfaction (VS)	FQ, SQ	0.824	0.680	FQ → VS = 0.198; SQ → VS = 0.495	FQ (medium), SQ (large); substantial explanatory and predictive power
Visitor Loyalty (VL)	VS, FQ, SQ	0.780	0.618	VS → VL = 0.393; FQ → VL = 0.001; SQ → VL = 0.022	VS (large), FQ (negligible), SQ (small); substantial explanatory and predictive power

**Table 8.** Path coefficients and hypothesis testing (with one-tailed, 95% CI)

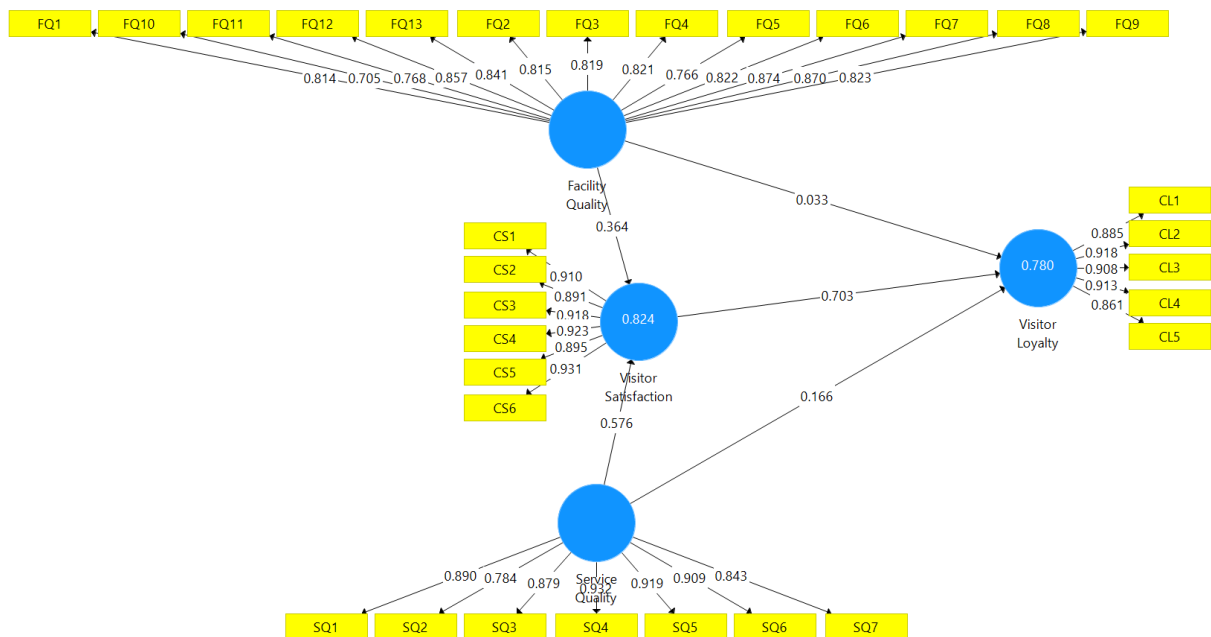
Hypothesis	Path	β	t-Value	p-Value	Decision
H <sub>1</sub>	FQ → VS	0.364	4.849	< 0.001	Supported
H <sub>2</sub>	SQ → VS	0.576	7.646	< 0.001	Supported
H <sub>3</sub>	VS → VL	0.703	8.896	< 0.001	Supported
H <sub>4</sub>	FQ → VS → VL (Indirect)	0.256	4.112	< 0.001	Supported
H <sub>5</sub>	SQ → VS → VL (Indirect)	0.405	6.050	< 0.001	Supported
Direct Effects	FQ → VL (Direct)	0.033	0.434	0.332	Not Supported
	SQ → VL (Direct)	0.166	1.736	0.042	Supported (Weak Direct Effect)

positively affected VS ( $\beta = 0.364, t = 4.849, p < 0.001$ ; H<sub>1</sub> supported). SQ had a stronger effect on VS ( $\beta = 0.576, t = 7.646, p < 0.001$ ; H<sub>2</sub> supported). VS strongly predicted VL ( $\beta = 0.703, t = 8.896, p < 0.001$ ; H<sub>3</sub> supported).

Indirect effects were significant: FQ → VS → VL ( $\beta = 0.256, t = 4.112, p < 0.001$ ; H<sub>4</sub> supported); SQ → VS → VL ( $\beta = 0.405, t = 6.050, p < 0.001$ ; H<sub>5</sub> supported). Direct FQ → VL was non-significant ( $\beta = 0.033, t = 0.434, p = 0.332$ ; full mediation). Direct SQ → VL was weakly significant ( $\beta = 0.166, t = 1.736, p = 0.042$ ; partial mediation).

### 4. DISCUSSION

This study examined how facility quality and service quality influence visitor satisfaction and visitor loyalty in Jakarta’s revitalized public green spaces, which function as important urban tourism destinations. Grounded in the quality–satisfaction–loyalty (Q-S-L) paradigm (Oliver, 1980), the service quality model (Parasuraman et al., 1988), and the attitude–behavior framework (Ajzen, 1991), the PLS-SEM results confirm that visitor satisfaction serves as the central mediating mechanism linking per-



**Figure 2.** Structural model output (SEM-PLS)

ceived quality to behavioral loyalty. These findings highlight the importance of experiential quality in shaping visitor engagement and reinforce the role of urban parks as spatially embedded tourism resources that contribute to destination attractiveness and sustainable competitiveness in rapidly urbanizing environments.

Facility quality significantly influenced visitor satisfaction, supporting H<sub>1</sub>. Consistent with environmental psychology and servicescape theory, well-maintained infrastructure enhances perceptions of comfort, safety, and environmental quality (Gehl, 2011; R. Kaplan & S. Kaplan, 1989). These findings align with prior research demonstrating that facility quality is essential for positive visitor evaluations in park and tourism settings (Chemedá et al., 2025; Shao & Chung, 2024). However, facility quality did not directly influence visitor loyalty, indicating that its effect operates entirely through satisfaction. This indicates that physical infrastructure contributes to sustained visitor engagement primarily through satisfaction-driven experiential evaluation.

Service quality exerted a stronger influence on visitor satisfaction, supporting H<sub>2</sub>. Consistent with the SERVQUAL framework, responsive management, effective communication, and visitor-oriented services strengthen emotional engagement and perceived destination quality (Parasuraman et al., 1988; Garín-Muñoz & Moral, 2017; Luo & Li, 2024). Service quality also demonstrated a weak but significant direct effect on visitor loyalty, alongside a stronger indirect effect through satisfaction, supporting H<sub>5</sub>. This indicates partial mediation, suggesting that while high-quality service interactions can independently influence loyalty, their primary effect occurs through satisfaction-driven experiential evaluation.

Visitor satisfaction strongly influenced visitor loyalty, supporting H<sub>3</sub> and confirming its role as the primary driver of behavioral loyalty. This finding is consistent with the Q-S-L paradigm and tourism research demonstrating that satisfied visitors are more likely to revisit destinations and engage in positive word-of-mouth (Oliver, 1980; Kotler & Keller, 2016; Hussain et al., 2023; Chemedá et al., 2025). In urban tourism contexts, this emphasizes the importance of delivering fulfilling and posi-

tive experiences to sustain visitor engagement and destination competitiveness.

The mediation analysis further confirmed that facility quality and service quality influence visitor loyalty indirectly through visitor satisfaction, supporting H<sub>4</sub> and H<sub>5</sub>. These findings reinforce prior research indicating that quality perceptions influence loyalty primarily through experiential and emotional responses rather than direct behavioral effects (Zeithaml et al., 1996; Garín-Muñoz & Moral, 2017). Service quality demonstrated the strongest overall influence, highlighting the importance of effective management and visitor-oriented service delivery in publicly managed tourism environments.

Overall, these findings extend the quality–satisfaction–loyalty paradigm to non-commercial urban tourism contexts, demonstrating that experiential quality plays a critical role in shaping visitor behavior in publicly managed tourism spaces. From a tourism management perspective, the results highlight how infrastructure quality, service delivery, and visitor experience interact to influence destination attractiveness and sustained engagement. Practically, urban tourism planners and park managers should adopt integrated management strategies that combine infrastructure investment with hospitality-oriented service delivery to enhance satisfaction-driven loyalty. Such strategies can strengthen the role of urban parks as sustainable tourism assets that contribute to destination competitiveness, visitor well-being, and long-term urban tourism development.

#### 4.1. Theoretical contribution

This study extends the quality–satisfaction–loyalty (Q-S-L) paradigm (Oliver, 1980) from traditional commercial tourism contexts to publicly managed urban parks in a rapidly urbanizing Southeast Asian megacity. By empirically validating visitor satisfaction as the central mediating mechanism linking facility quality and service quality to visitor loyalty, the findings demonstrate how tangible and intangible quality dimensions jointly shape affective and behavioral outcomes in non-commercial public tourism environments. This paper integrates perspectives from service management, environmental psychology, and sustainable urban

tourism, refining the Q-S-L framework for spatially embedded, community-oriented tourism resources. By doing so, it advances tourism management and urban tourism scholarship by providing empirical evidence on how perceived quality and satisfaction mechanisms influence visitor engagement and loyalty formation in publicly accessible urban tourism destinations.

## 4.2. Practical implications

The findings offer important implications for urban tourism planners, park managers, and policymakers seeking to enhance the visitor experience and the sustainable competitiveness of destinations.

First, maintaining high facility quality is essential for providing a supportive physical environment that promotes visitor comfort, accessibility, and positive experiential evaluation. Investments in infrastructure, cleanliness, accessibility, and sustainable amenities strengthen the foundation for visitor satisfaction and engagement.

Second, service quality plays a critical role in shaping emotional and experiential responses. Hospitality-oriented service practices, including responsive management, visitor assistance, and proactive maintenance, can strengthen visitor trust, satisfaction, and long-term attachment to urban tourism spaces.

Third, visitor satisfaction serves as the primary pathway through which quality perceptions translate into loyalty. Implementing continuous satisfaction monitoring through feedback systems and digital platforms can support adaptive management and improve experience quality.

Finally, integrated management strategies that combine high-quality facilities with effective service delivery are essential for transforming public parks into sustainable urban tourism assets that encourage repeat visitation, positive word-of-mouth, and long-term destination competitiveness.

These findings are particularly relevant for emerging megacities, where revitalized public green spaces play a critical role in enhancing tourism attractiveness, urban livability, and community well-being.

## 4.3. Limitations and future research directions

Despite its contributions, this study has several limitations. The analysis was conducted in public parks within Jakarta, which may limit the generalizability of the findings to other geographic or cultural contexts. The cross-sectional design also restricts the ability to examine changes in visitor perceptions over time.

Future research could extend this work through comparative studies across cities, tourism destinations, and cultural settings. Longitudinal and experimental designs may provide deeper insights into how satisfaction and loyalty evolve over time. Incorporating additional constructs, such as place attachment, perceived value, emotional experience, and authenticity, could further enhance the understanding of visitor behavior. The integration of spatial and behavioral data, including visitor movement patterns, GIS-based accessibility analyses, and digital engagement metrics, may also provide valuable insights into the formation of satisfaction and loyalty in urban tourism environments.

---

## CONCLUSION

This study applied the quality–satisfaction–loyalty framework to examine how facility quality and service quality influence visitor satisfaction and visitor loyalty in Jakarta’s urban parks. The findings demonstrate that while well-maintained physical infrastructure provides the structural foundation for visitor experience, service quality and experiential factors play a more influential role in shaping satisfaction and long-term behavioral loyalty.

Visitor satisfaction emerged as the central mechanism linking perceived quality to loyalty, confirming its critical role in driving repeat visitation and positive word-of-mouth in publicly managed tourism

environments. These results highlight the importance of integrated experience management strategies that combine physical infrastructure development with effective service delivery.

From a tourism management perspective, the findings reinforce the role of urban parks as important urban tourism resources that contribute to destination attractiveness, visitor engagement, and sustainable urban tourism development. By extending the quality–satisfaction–loyalty paradigm to public urban tourism spaces, this study offers valuable theoretical and practical insights to improve visitor experience and strengthen destination competitiveness in rapidly urbanizing megacities.

## AUTHOR CONTRIBUTIONS

Conceptualization: Arjuna Wiwaha, Junaid Ali Saeed Rana.

Data curation: Suwandi.

Formal analysis: Suwandi, Arjuna Wiwaha.

Investigation: Suwandi, Arjuna Wiwaha, Junaid Ali Saeed Rana.

Methodology: Arjuna Wiwaha, Junaid Ali Saeed Rana.

Project administration: Suwandi.

Resources: Junaid Ali Saeed Rana.

Software: Junaid Ali Saeed Rana.

Supervision: Arjuna Wiwaha, Junaid Ali Saeed Rana.

Validation: Suwandi, Arjuna Wiwaha, Junaid Ali Saeed Rana.

Visualization: Suwandi, Junaid Ali Saeed Rana.

Writing – original draft: Suwandi, Junaid Ali Saeed Rana.

Writing – review & editing: Junaid Ali Saeed Rana.

## REFERENCES

- Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179-211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)
- Akroush, M. N., Jraisat, L. E., Kurdieh, D. J., AL-Faouri, R. N., & Qatu, L. T. (2016). Tourism service quality and destination loyalty – The mediating role of destination image from international tourists' perspectives. *Tourism Review*, 71(1), 18-44. <https://doi.org/10.1108/TR-11-2014-0057>
- Alamasi, R., Asfour, O. S., & AlMahdy, O. E. (2024). Users' satisfaction with the urban design of naturebased parks: A case study from Saudi Arabia. *Urban Science*, 8(4), Article 219. <https://doi.org/10.3390/urbansci8040219>
- Andayani, S. A., Umyati, S., Dani, U., & Turnip, A. (2021). Service quality and interest impact on satisfaction and loyalty of agrotourism visitors. *IOP Conference Series: Earth and Environmental Science*, 748(1), Article 012041. Retrieved from <https://iopscience.iop.org/article/10.1088/1755-1315/748/1/012041>
- Baba, M. M. (2018). Service quality and customer loyalty: A study in telecom sector. *Asian Review of Social Sciences*, 7(1), 60-66. <https://doi.org/10.51983/arss-2018.7.1.1398>
- Bitner, M. J. (1992). Servicescapes: The impact of physical surroundings on customers and employees. *Journal of Marketing*, 56(2), 57-71. <https://doi.org/10.1177/002224299205600205>
- Carvache-Franco, M., Carvache-Franco, O., Carvache-Franco, W., & Villagómez-Buele, C. (2020). From satisfaction in eco-tourism to loyalty in a national park. *GeoJournal of Tourism and Geosites*, 28(1), 191-202. <https://doi.org/10.30892/gtg.28115-462>
- Chemeda, B. A., Woldemedhin, D. G., Mesfin, D., & Terefe, F. (2025). Visitors' fondness and satisfaction to urban recreational parks: The case of Bihere-Tsige Park, Addis Ababa, Ethiopia. *Discover Global Society*, 3, Article 42. <https://doi.org/10.1007/s44282-025-00164-x>
- Chin, W. W. (1998). The partial least squares approach to structural equation modeling. In G. A. Marcoulides (Ed.), *Modern Methods for Business Research* (pp. 295-336). Lawrence Erlbaum Associates Publishers. Retrieved from <https://psycnet.apa.org/record/1998-07269-010>
- Cronin, J. J., & Taylor, S. A. (1992). Measuring service quality: A reexamination and extension. *Journal of Marketing*, 56(3), 55-68. <https://doi.org/10.1177/002224299205600304>
- Dharmawan, D. A., & Sitio, A. (2020). Related impact from service quality and product quality towards customer satisfaction as well as its implications to customer loyalty at PT. Cianjur Artha Makmur. *Dinasti International Journal of Management*

- Science*, 2(1), 101-111. <https://doi.org/10.31933/dijms.v2i1.535>
12. Diamantopoulos, A., & Sigauw, J. A. (2006). Formative versus reflective indicators in organizational measure development: A comparison and empirical illustration. *British Journal of Management*, 17(4), 263-282. <https://doi.org/10.1111/j.1467-8551.2006.00500.x>
  13. Du, Y., & Zhao, R. (2022). Research on the development of urban parks based on the perception of tourists: A case study of Taihu Park in Beijing. *International Journal of Environmental Research and Public Health*, 19(9), Article 5287. <https://doi.org/10.3390/ijerph19095287>
  14. Felappi, J. F., Sommer, J. H., Falkenberg, T., Terlau, W., & Kötter, T. (2024). Urban park qualities driving visitors' mental well-being and wildlife conservation in a Neotropical megacity. *Scientific Reports*, 14, Article 4856. <https://doi.org/10.1038/s41598-024-55357-2>
  15. Gajić, T., Vukolić, D., Zrnić, M., & Lóránt Dénes, D. (2023). The quality of hotel service as a factor of achieving loyalty among visitors. *Hotel and Tourism Management*, 11(1), 67-77. <https://doi.org/10.5937/menhottur2301067G>
  16. Garín-Muñoz, T., & Moral, M. J. (2017). Determinants of satisfaction with an urban tourism destination: The case of Barcelona. *Journal of Reviews on Global Economics*, 6, 113-128. <https://doi.org/10.6000/1929-7092.2017.06.10>
  17. Gehl, J. (2011). *Life between buildings: Using public space*. Washington DC: Island Press.
  18. Giles-Corti, B., Timperio, A., Bull, F., & Pikora, T. (2005). Understanding physical activity environmental correlates: Increased specificity for ecological models. *Exercise and Sport Sciences Reviews*, 33(4), 175-181. <https://doi.org/10.1097/00003677-200510000-00005>
  19. Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017). *A primer on partial least squares structural equation modeling (PLS-SEM)* (2nd ed.). Sage.
  20. Hair, J. F., Hult, G. T. M., Ringle, C., & Sarstedt, M. (2021). *A primer on partial least squares structural equation modeling (PLS-SEM)* (3rd ed.). Sage.
  21. Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review*, 31(1), 2-24. <https://doi.org/10.1108/EBR-11-2018-0203>
  22. Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, 43(1), 115-135. <https://doi.org/10.1007/s11747-014-0403-8>
  23. Hussain, A., Li, M., Kanwel, S., Asif, M., Jameel, A., & Hwang, J. (2023). Impact of tourism satisfaction and service quality on destination loyalty: A structural equation modeling approach concerning China resort hotels. *Sustainability*, 15(9), Article 7713. <https://doi.org/10.3390/su15097713>
  24. Jaafar, N., & Tudin, R. (2010). Uparqual: The development of an urban park satisfaction measurement scale. *International Journal of Business and Society*, 11(2), 1-16. Retrieved from [https://www.academia.edu/82300942/Uparqual\\_The\\_Development\\_of\\_an\\_Urban\\_Park\\_Satisfaction\\_Measurement\\_Scale](https://www.academia.edu/82300942/Uparqual_The_Development_of_an_Urban_Park_Satisfaction_Measurement_Scale)
  25. Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. Cambridge University Press.
  26. Kaulu, B., Nakalinda, A., Zya, E., Phiri, H., Haabazoka, L., & Kaulu, G. (2025). Customer satisfaction as mediator in the relationship between higher education service quality and student customer loyalty. *European Journal of Management Studies*, 30(3-4), 287-300. <https://doi.org/10.1108/EJMS-05-2024-0045>
  27. Kotler, P., & Keller, K. L. (2016). *Marketing management* (15<sup>th</sup> ed.). Pearson Education.
  28. Luo, J., & Li, X. (2024). Perceived service quality and visitors' sustainable visit intentions in theme parks: Empirical analysis on the THEMEQUAL scale. *Frontiers in Sustainable Tourism*, 3, Article 1387048. <https://doi.org/10.3389/frsut.2024.1387048>
  29. Nasution, A. A. S., Lubis, S., & Purwoko, A. (2025). Public satisfaction in Medan green public parks: The role of service quality, facilities, and trust. *South Asian Journal of Social Studies and Economics*, 22(1), 96-107. <https://doi.org/10.9734/sajsse/2025/v22i1947>
  30. Nursyamsiah, R. A., & Setiawan, R. P. (2023). Does place attachment act as a mediating variable that affects revisit intention toward a revitalized park? *Alexandria Engineering Journal*, 64, 999-1013. <https://doi.org/10.1016/j.aej.2022.08.030>
  31. Oliver, R. L. (1980). A cognitive model of the antecedents and consequences of satisfaction decisions. *Journal of Marketing Research*, 17(4), 460-469. <https://doi.org/10.2307/3150499>
  32. Oliver, R. L. (1999). Whence consumer loyalty? *Journal of Marketing*, 63(4), 33-44. <https://doi.org/10.1177/00222429990634s105>
  33. Pakurár, M., Haddad, H., Nagy, J., Popp, J., & Oláh, J. (2019). The service quality dimensions that affect customer satisfaction in the Jordanian banking sector. *Sustainability*, 11(4), Article 1113. <https://doi.org/10.3390/su11041113>
  34. Pangestu, R. A., Handoko, T. H., & Widodo, Z. D. (2023). Influence of service quality and facilities on visitor satisfaction: New Royal Adventure visitor case study. *International Journal of Asian Business and Management*, 2(4), 485-490. <https://doi.org/10.55927/ijabm.v2i4.5124>
  35. Parasuraman, A., Zeithaml, V. A., & Berry, L. L. (1988). SERVQUAL: A multiple-item scale for measuring consumer perceptions of service quality. *Journal of Retailing*, 64(1), 12-40. Retrieved from <https://www.marketeurexpert.fr/wp-content/uploads/2023/12/servqual.pdf>

36. Praharjo, A. (2020). The effect of service quality on satisfaction and loyalty visitors at Sengkaling Recreational Park. *Jurnal Manajemen Bisnis*, 10(1), 74-86. <https://doi.org/10.22219/jmb.v10i1.12091>
37. Samsudin, & Suhalya, S. (2025). The influence of service quality and public trust on public satisfaction in using the Jakevo application in Pulo Village, South Jakarta City. *Neo Journal of Economy and Social Humanities*, 4(1), 174-178. <https://doi.org/10.56403/nejesh.v4i1.305>
38. Santoso, Y., Rachmawati, I., & Handoko, Y. (2025). The effect of service quality on loyalty, through customer satisfaction at region development bank of Papua LLC Branch Agats. *Journal of Management: Small and Medium Enterprises (SMEs)*, 18(1), 599-612. <https://doi.org/10.35508/jom.v18i1.17644>
39. Shah, A. A., Bilal, H., & Sanober, I. (2024). Nexus between service quality & customer loyalty: Mediating role of customer satisfaction in banking sector. *Journal of Social Research Development*, 5(1), 37-46. <https://doi.org/10.53664/JSRD/05-01-2024-04-37-46>
40. Shao, C., & Chung, W. (2024). The impact of park environmental characteristics and visitor perceptions on visitor emotions from a cross-cultural perspective. *Urban Forestry & Urban Greening*, 102, Article 128575. <https://doi.org/10.1016/j.ufug.2024.128575>
41. Suminar, L., Ramadhani, D. A. B., & Endriyanto, D. (2024). Assessing urban waterfront public space service quality using importance-performance analysis (IPA). *ARTEKS: Jurnal Teknik Arsitektur*, 9(2), 155-168. <https://doi.org/10.30822/arteks.v9i2.2868>
42. Umul, D. S., Wijaya, N. M. S., & Widyatmaja, I. G. N. (2023). The effect of service quality and domestic tourist satisfaction on intention to revisit marine tourism in Komodo National Park. *European Modern Studies Journal*, 7(1). [https://doi.org/10.59573/emsj.7\(1\).2023.17](https://doi.org/10.59573/emsj.7(1).2023.17)
43. Vu, T. (2021). *Service quality and its impact on customer satisfaction* (Undergraduate Thesis). University of Northampton. <https://doi.org/10.6084/m9.figshare.17089454>
44. Zeithaml, V. A., Berry, L. L., & Parasuraman, A. (1996). The behavioral consequences of service quality. *Journal of Marketing*, 60(2), 31-46. <https://doi.org/10.1177/002224299606000203>
45. Zhang, H., Yang, R., Gui, L., & Yang, Q. (2025). Key factors and configuration analysis of improving tourist loyalty in forest park: Evidence from Yingde National Forest Park, South China. *Forests*, 16(3), 463. <https://doi.org/10.3390/f16030463>
46. Zhao, Z., He, Q., Zhang, Y., Liu, S., & Yang, Y. (2025). Assessing cross-cultural urban park emotional wellbeing impact in Shanghai and London. *Scientific Reports*, 15, Article 18892. <https://doi.org/10.1038/s41598-025-03599-z>