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Co-Productive Engagement, Service-Quality Perception, and Sustained Use of Fresh-Grocery Digital Platforms in Guangdong: A Boundary-Conditional Mediation Model with Technology-Related Apprehension

Qiuying Yue¹, Weixiang Gan^{2,*}, Tara Ahmed Mohammed¹, Shashi Kant Gupta², Mengfei Xiao², Xiaolin Song³, Jialin Liu⁴

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Abstract: The rapid growth of China's online fresh-grocery market has not translated into consistent user retention. Although prior research recognises user engagement on digital platforms, it remains unclear which forms of engagement foster sustained platform use and through what psychological mechanisms. Drawing on the stimulus-organism-response framework, this study examines four dimensions of co-productive engagement—task cognition, information seeking, effort expenditure, and human-computer interaction—as separate antecedents of continuance intention. Perceived service quality is modelled as a mediator, and technology-related apprehension as a moderator. Survey data from 550 fresh-grocery users in Guangdong Province were analysed using partial least squares structural equation modelling (SmartPLS 4.1.1). All four engagement dimensions positively influence perceived service quality, which in turn increases continuance intention and partially mediates these relationships. Effort expenditure shows the strongest effect. Technology-related apprehension negatively affects perceived service quality and significantly weakens only the information-seeking pathway. Within the limits of a cross-sectional, non-probability sample, the findings extend the participatory perspective of the stimulus-organism-response framework, identify service quality as a key transmission mechanism, and indicate that technology-related apprehension influences engagement selectively rather than uniformly. The results suggest that platforms should simplify information processing for apprehensive users while encouraging forms of engagement that make user effort more rewarding.

Keywords: Fresh-grocery e-commerce; Co-productive engagement; Service-quality; Continuance intention; Technology-related apprehension; Partial-least-squares structural equation modelling (PLS-SEM)

Introduction

China's digital-retail apparatus is no longer a frontier sector. Within this established market, the rapid-fulfilment grocery segment - operated by integrated online-to-offline players such as Hema, JD Fresh, Dingdong Maicai, Meituan Maicai, Pupu, and Pinduoduo's Duoduo Maicai - combines

cold-chain logistics with mobile interfaces to support recurrent household purchasing. Because these services are easy to compare and switch, the strategic focus increasingly extends beyond first-time adoption toward retaining experienced users ([Gao et al., 2015](#); [Kim & Yum, 2024](#); [Monoarfa et al., 2024](#)). Sectoral growth has decelerated, and the conversation among operators has shifted from acquiring new

¹ SEGi University, Kota Damansara, Petaling Jaya, Selangor 47810, Malaysia; ² Lincoln University College, Petaling Jaya, Selangor 47301, Malaysia; ³ Nanjing Tech University, Nanjing 210023, China; ⁴ Taylor's University, No. 1, Jalan Taylor's, 47500 Subang Jaya, Selangor, Malaysia.

* Corresponding author. Email: Gabriel1995@qq.com.

users to keeping the ones already on the platform ([Liu & Chen, 2025](#); [Xiao & Wang, 2025](#); [Wu & Liu, 2025](#)).

Retention is not a neutral problem in this context. Fresh groceries differ from packaged goods on several dimensions that bear directly on user behaviour: products perish, quality cannot be inspected pre-purchase, fulfilment is time-critical, and any single failed delivery cascades into household disruption ([Cui, 2025](#); [Ren et al., 2025](#); [Jia, 2024](#)). Reported in-channel loss rates of 20-25% for perishables suggest substantial backstage volatility that is, sooner or later, reflected in the user's evaluation of the platform ([Liu et al., 2024](#); [Tao, 2025](#); [Sun, 2025](#)). Against this backdrop, the user is asked to do considerable work themselves - inspecting product images and provenance, comparing time-slot windows, parsing promotion stacks, communicating with chat agents, providing post-delivery feedback - and that work is itself an input to whether the user perceives the service as competently delivered ([Xie et al., 2008](#); [Wu & Chen, 2017](#); [Shen, 2025](#)).

A genuine theoretical puzzle sits underneath the practitioner concern. Three discrete strands of literature speak to the retention question but rarely come into contact. The participation literature (rooted in service-dominant and co-creation thinking) treats user engagement as a generic input into value creation but seldom interrogates the internal architecture of that engagement ([Wu & Chen, 2017](#); [Sadighha et al., 2025](#); [Wang & Wei, 2011](#)). The service-quality literature, traceable to Parasuraman and colleagues, supplies an evaluative scaffold but typically positions perceived quality as either an antecedent or an outcome rather than as a transmitting mechanism ([Espino-Rodriguez & Rodriguez-Diaz, 2021](#); [He et al., 2023](#); [Brochado et al., 2019](#); [Meijerink & Schoenmakers, 2021](#)). The continuance-intention literature, originating in the information-systems tradition, isolates retention drivers but tends to do so without specifying how participatory behaviours upstream feed into those drivers ([Liu X.N. et al., 2025](#); [Cheng et al., 2024](#); [Chi et al., 2024](#); [Yi & Zhu, 2025](#); [Fu & Zhang, 2025](#)). And almost none of these strands distinguish those users whose interaction with the platform is hampered by an underlying apprehension toward the technology itself ([Tarafdar et al., 2019](#); [Tarhini et al., 2021](#)).

The present study addresses this puzzle by integrating, within a single estimable structural model, four interlocking propositions. First, user engagement on a fresh-grocery platform should be decomposed rather than aggregated; we treat it as a four-strand construct consisting of procedural awareness of platform mechanics (task cognition), proactive informational acquisition (information seeking), behavioural-resource investment (effort expenditure), and interface-mediated interaction (human-computer interaction). Second, the path from engagement to behavioural intention is not exclusively direct; it is partly routed through the user's overall judgement of service quality - a perceptual organism in stimulus-organism-response terms. Third, that perceptual organism translates into a behavioural response, namely the user's stated intention to keep using the platform. Fourth, an individual-difference variable - technology-

related apprehension - should be permitted both a direct depressing effect on service-quality perception and a path-conditional moderating effect, because not every engagement strand is equally cognitively demanding.

Relative to the earlier report of the core model using the same dataset ([Yue et al., 2026](#)), the present manuscript makes four analytical and reporting contributions. Theoretically, it formalises co-productive engagement as an organising umbrella for four distinct first-order constructs rather than as a measured higher-order factor. Methodologically, it reports a fully specified mediation-moderation structural model, including direct, indirect, total, and proportion-mediated estimates, alongside fuller measurement and robustness diagnostics. Empirically, it documents the path-specific moderation of technology-related apprehension with a simple-slope analysis while qualifying the pattern to this sample. Practically, it offers design-oriented guidance, tempered by the modest effect sizes observed, that distinguishes general-purpose engagement design from apprehension-sensitive interface design.

The remainder of the paper proceeds as follows. Section 2 situates the empirical setting and surveys the four literatures we draw on. Section 3 develops the conceptual model and articulates thirteen hypotheses. Section 4 documents the research design, sampling, instrumentation, and analytical procedure. Section 5 presents descriptive, measurement-model, and structural-model results, including reliability, validity, multicollinearity, common-method bias, path-coefficient, mediation, and simple-slope evidence. Section 6 discusses interpretive, theoretical, and managerial implications, and the closing sections flag limitations and avenues for future enquiry.

Empirical Setting and Literature Foundations

The fresh-grocery channel in Guangdong

Guangdong Province offers an empirically apposite setting for this enquiry on several grounds ([Li & Jiang, 2025](#); [Liu Y.C. et al., 2025](#); [Wang & Li, 2025](#)). It is one of China's most digitally penetrated regions, with mobile-internet adoption well above the national average and a household-spending profile that has been measurably reshaped by application-mediated grocery purchasing. Major platforms operate at scale in the province - national-network apps such as Meituan Maicai, JD Daojia, and Hema coexist with regionally rooted services such as Pupu, Qian Dama, and local-supermarket apps such as Walmart/Sam's Club, Vanguard, and Yonghui Life. The provincial geography spans densely urban core cities of the Pearl River Delta (Guangzhou, Shenzhen, Foshan, Dongguan), peripheral Delta cities (Zhuhai, Zhongshan, Huizhou, Jiangmen, Zhaoqing), and second- and third-tier cities in eastern, western, and northern Guangdong (Shantou, Shanwei, Chaozhou, Jieyang, Zhanjiang, Maoming, Yangjiang, Yunfu, Shaoguan, Qingyuan, Meizhou, Heyuan), providing useful behavioural heterogeneity within a single

administrative jurisdiction (although, given the non-probability design detailed in Section 4.2, statistical generalisation to the full population is not claimed) (Yang J., 2025; Liu Y.C. et al., 2025).

Two consumption-side trends warrant particular note. First, the post-pandemic normalisation of digital grocery use has produced a base of users who are not novices but who nonetheless face new app features (live-stream sourcing, AR product previews, conversational assistants, biometric checkout) at a steady rate, exposing the gap between competence with the platform's basic functions and ease with its newer ones (Singh et al., 2023). Second, the segment is dominated by repeat-purchase rhythms (weekly or twice-weekly) rather than one-off acquisitions, which raises the operational weight of any factor that influences whether the user returns next week (Yang F.M., 2025; Fei & Chen, 2025; Liu W.J. & Liu J.H., 2025).

Continuance intention as a post-adoption behavioural construct

The dependent construct in this study - continuance intention - belongs to the post-adoption family of behavioural-intention measures originally formalised in the information-systems literature and subsequently extended into platform-based digital commerce (Liu X.N. et al., 2025; Davis & Chandrasekar, 2025; Yu F.H., 2025; Zhou J.H., 2025). Continuance differs in important ways from adoption. Adoption asks whether a user will initiate a relationship with a system; continuance asks whether the user, having already initiated and reflected on the experience, will sustain it. The literature consistently identifies satisfaction, perceived performance, trust, expectation-performance fit, and habit formation as the proximate drivers of continuance (Cheng et al., 2024; Sharma et al., 2024).

In digital-grocery contexts, continuance has special bite. Switching costs are low (alternative apps are one tap away), basket sizes are recurrent rather than monolithic, and even small dips in confidence can dissolve a habit (Monoarfa et al., 2024; Yang F.M., 2025; Jiao et al., 2025). Continuance has been studied across many adjacent settings - smart-education platforms (Fu & Zhang, 2025), mobile-government applications (Yi & Zhu, 2025), internet-medical platforms (Liu X.N. et al., 2025; Yu H.X., 2025), AR retail applications (Song et al., 2025), AI-assistant chatbots (Xu et al., 2025), social-networking apps (Lin, 2025; Yang Z.Y., 2025), AIGC mobile apps (Zhou J.H., 2025), and even VR exhibitions (Wang M. et al., 2023; Zhang Q. et al., 2025) - each enriching the inventory of antecedents but each also leaving open the question of how user-side participatory behaviours feed in.

Related evidence from Douyin shows that content practices can erode platform stickiness through declining user trust, while algorithmic regulation can buffer this retention loss (Gan et al., 2025).

Co-productive engagement: Why aggregation loses information

The construct we label "co-productive engagement" sits in the long tradition that conceptualises customers as participants in value creation rather than passive recipients of provider-delivered service (Xie et al., 2008; Wu & Chen, 2017; Verhagen et al., 2014). The conceptual move that organises this paper is the disaggregation of that construct into four observable strands that map cleanly onto distinct cognitive and behavioural resources. We adopt this decomposition because aggregated treatments cannot tell us, for instance, whether the apprehensive user is suffering at the informational-acquisition step or at the interaction step - a distinction with sharp design consequences.

A clarification of construct status is warranted. We use co-productive engagement as an organising, umbrella concept rather than as a measured higher-order (second-order) latent variable. Empirically, the four strands, task cognition, information seeking, effort expenditure, and human-computer interaction, are modelled as four distinct first-order reflective constructs, each entered as a separate antecedent of service-quality perception. We do not estimate a reflective-reflective or formative-reflective higher-order construct, and we make no claim that the four strands are interchangeable indicators of a single latent engagement factor. Accordingly, references throughout to the "architecture" or "decomposition" of engagement denote this conceptual organisation, and the results should be read as evidence about four related but separable engagement dimensions rather than about a superordinate construct.

The first strand, task cognition, refers to a user's understanding of platform rules, navigation logic, promotion rules, and the procedural sequence required to convert browsing into delivery. Conceptually it draws on job-characteristics work that links role clarity to performance and motivation; in digital retail it has been recast as a user-side awareness of how recommender systems, filtering options, and check-out flows actually operate. It is foundational in the sense that the other three strands depend on it.

The second strand, information seeking, captures the user's proactive collection and verification of product- and service-relevant information from in-app and external sources - reading provenance labels, comparing freshness ratings, scrutinising user reviews, reading promotion fine print. For perishable goods this strand is unusually consequential because pre-purchase physical inspection is impossible (Qi et al., 2024; Shen, 2025; Wang & Li, 2025).

The third strand, effort expenditure, captures the time, attention, and behavioural-resource investment a user is willing to make - daily check-ins, custom requests in order notes, schedule adjustments to receive deliveries, participation in review programmes, tolerance of minor product imperfections (Wu & Chen, 2017). It is the most observable of the four strands and frequently the most consequential for service-quality perception, because effort tends to crystallise into a sense of investment and ownership.

The fourth strand, human-computer interaction, captures the interaction quality with the platform's digital interface - the smoothness of filters, the helpfulness of intelligent search, the responsiveness of in-app customer service, the seamlessness of the browse-cart-checkout chain ([Chattaraman et al., 2012](#); [Huang & Benyoucef, 2013](#); [Tarafdar et al., 2019](#)). Where the first three strands describe what the user does, this fourth strand describes how the platform reciprocates.

The decomposition is conceptually clean and, apart from the authors' earlier report using the same dataset ([Yue et al., 2026](#)), remains uncommon in the fresh-grocery literature, where prior empirical work has either combined the dimensions or studied them in smaller subsets ([Yang F.M., 2025](#); [Monoarfa et al., 2024](#); [Ren et al., 2025](#); [Wang & Li, 2025](#)).

Service-quality perception as cognitive bridge

The service-quality construct used here is grounded in the SERVQUAL tradition ([Parasuraman et al., 1988](#)) but adapted in two ways. First, the five classical dimensions - tangibles, reliability, responsiveness, assurance, empathy - are recast for a perishable-delivery context, where tangibles include packaging integrity and the delivery uniform; reliability turns on freshness and on-time fulfilment; responsiveness means the speed of after-sales remediation; assurance means the credibility of provenance disclosure and the security of payment; and empathy includes regionally tailored offerings (e.g., recommending Cantonese-cuisine ingredients) and flexible delivery windows ([Kim & Yum, 2024](#); [Monoarfa et al., 2024](#)).

Second - and this is the conceptual move that distinguishes our use of the construct from much prior work - we treat service-quality perception as a transmitting mechanism rather than a static evaluation. In the language of stimulus-organism-response models, it is the organism that receives the participatory stimulus and translates it into a behavioural response ([Mehrabian & Russell, 1974](#); [Cheng et al., 2024](#); [Gao et al., 2015](#)). Service quality, in this formulation, is what stands between what the user does on the platform and whether the user comes back next week.

Technology-related apprehension as a boundary condition

Technology-related apprehension - an enduring sense of discomfort, friction, or anxious anticipation when interacting with digital systems - has been studied principally in the technology-adoption tradition ([Tarafdar et al., 2019](#); [Tarhini et al., 2021](#); [Singh et al., 2023](#); [Sharma et al., 2024](#)). Most treatments hypothesise a generalised inhibitory effect: apprehensive users do less, evaluate less favourably, and continue less reliably. We retain that baseline expectation for the direct effect on service-quality perception but argue that the moderating effect should be path-conditional. Apprehension should weigh on routes that demand active information processing and cognitive filtering (i.e., information seeking) but should weigh less on routes that are essentially behavioural (effort expenditure) or that depend on the plat-

form's design quality (human-computer interaction) or that pre-suppose existing rule-comprehension (task cognition).

This nuanced expectation is consistent with recent empirical work that finds heterogeneity rather than uniformity in technology-related affective burdens. It also aligns with the technostress-trifecta proposal that techno-distress is task-specific rather than person-specific ([Tarafdar et al., 2019](#)).

Complementary evidence from AI-personalised digital platforms shows that consumer engagement translates into loyalty more strongly when algorithmic trust is high, reinforcing the need to model technology-specific boundary conditions ([Xiao et al., 2025](#)).

Conceptual Model and Hypotheses

The conceptual model contains thirteen hypothesised relations. Four direct effects (H1a-H1d) link the engagement dimensions to service-quality perception. One direct effect (H2) links service-quality perception to continuance intention. Four moderating effects (H3a-H3d) propose that technology-related apprehension dampens the four engagement-to-perception routes. Four additional direct effects (H4a-H4d) link the engagement dimensions to continuance intention, allowing a formal test of partial mediation. The model, including the direct engagement-to-continuance paths shown as dashed arrows, is depicted in **Figure 1**.

From engagement strands to service-quality perception

The standard expectation-confirmation logic implies that perceived service quality - an aggregated cognitive judgement about platform performance - forms the most stable basis for the user's intention to keep using the platform ([Kim & Yum, 2024](#)). Where service quality is judged high, repeat use becomes the path of least resistance; where it is judged low, switching is comparatively easy because the rival apps are one tap away.

H1a. Task cognition is positively related to service-quality perception. Information seeking allows the user to overcome the unusually high pre-purchase uncertainty of perishable goods. The user who reads a provenance label, compares supplier ratings, and checks delivery-window logistics enters into the purchase with calibrated expectations that the platform can more easily satisfy. Information seeking thereby raises perceived reliability and assurance.

H1b. Information seeking is positively related to service-quality perception. Effort expenditure raises perceived quality through two routes: instrumental (more effort surfaces more relevant information and unlocks better matched delivery slots) and psychological (effort fosters a sense of co-production and ownership that biases evaluation upward). Because behavioural investment is directly observable and

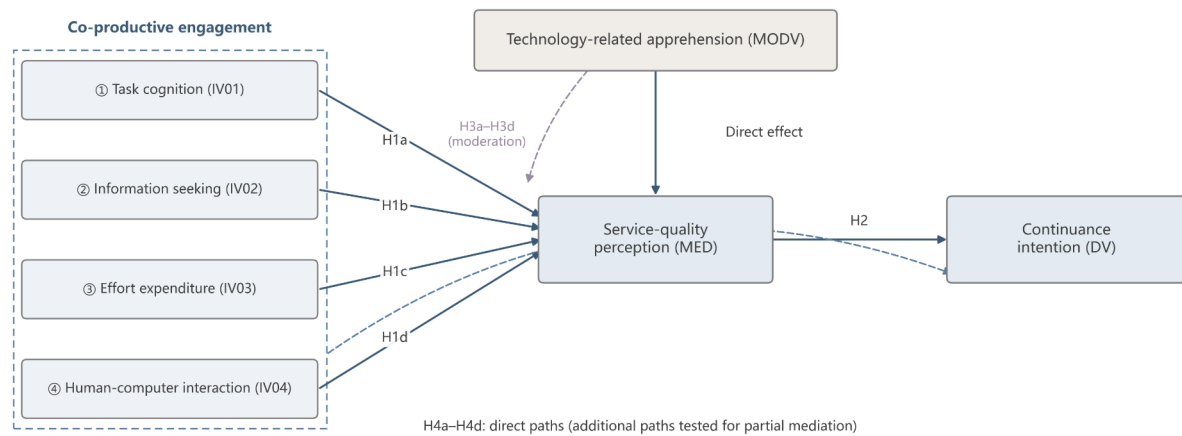


Figure 1 | Conceptual research framework

Solid arrows denote the hypothesised paths (H1a–H1d, H2); the dashed arrows denote the moderation of the four engagement→service-quality paths by technology-related apprehension (H3a–H3d) and the additional direct engagement→continuance paths (H4a–H4d).

personally costly, its quality-enhancing effect should be the strongest of the four.

- H1c.** Effort expenditure is positively related to service-quality perception. Human-computer interaction translates platform capability into perceptible smoothness. A clean filtering pane, a precise intelligent search, an attentive chatbot, and a seamless purchase chain are all read as evidence of quality. Conversely a clunky interface is read as low quality regardless of backstage performance.
- H1d.** Human-computer interaction is positively related to service-quality perception.

From service-quality perception to continuance intention

The standard expectation-confirmation logic implies that perceived service quality - an aggregated cognitive judgement about platform performance - forms the most stable basis for the user's intention to keep using the platform (Yu Y. et al., 2024; Nguyen et al., 2024; Kim & Yum, 2024; Dandis et al., 2026; Utami et al., 2025). Where service quality is judged high, repeat use becomes the path of least resistance; where it is judged low, switching is comparatively easy because the rival apps are one tap away.

- H2.** Service-quality perception is positively related to continuance intention.

Although the framework routes engagement through perceived service quality, the engagement dimensions may also influence continuance intention directly, for example, through habit formation or accumulated familiarity that bypasses explicit quality evaluation. To represent this possibility in the model, and to enable a formal test of partial versus full mediation, we additionally estimate direct engagement-to-continuance paths and state the following hypotheses:

- H4a.** Task cognition is positively related to continuance intention.
- H4b.** Information seeking is positively related to continuance intention.
- H4c.** Effort expenditure is positively related to continuance intention.
- H4d.** Human-computer interaction is positively related to continuance intention.

We further expect each engagement dimension to exert a positive indirect effect on continuance intention through service-quality perception; the joint presence of a significant direct effect and a significant indirect effect would indicate complementary partial mediation.

Technology-related apprehension as path-conditional moderator

For each engagement strand, we propose a moderating effect of technology-related apprehension. Our prior, however, is asymmetric: the moderating effect should be largest for the route that depends most heavily on cognitive-informational processing.

- H3a.** Technology-related apprehension dampens the task-cognition to service-quality-perception relation.
- H3b.** Technology-related apprehension dampens the information-seeking to service-quality-perception relation.
- H3c.** Technology-related apprehension dampens the effort-expenditure to service-quality-perception relation.
- H3d.** Technology-related apprehension dampens the human-computer-interaction to service-quality-perception relation.

Table 1 | Construct definitions, item-set composition, and adaptation sources for the seven latent variables

Construct (Code)	Operational definition in the fresh-grocery context	Items	Principal adaptation sources
Task cognition (IV01)	A user's procedural understanding of platform rules, navigation flow, promotion logic, and the steps needed to translate browsing into a delivered order	5	Hackman & Oldham (1976); Xie et al. (2008); Wu & Chen (2017)
Information seeking (IV02)	A user's proactive acquisition and verification of product- and service-related information from in-app and external sources	5	Punj & Staelin (1983); Xie et al. (2008)
Effort expenditure (IV03)	The time, attention, and behavioural-resource investment a user is willing to make to obtain platform benefits and complete purchase tasks	5	Xie et al. (2008); Wu & Chen (2017)
Human-computer interaction (IV04)	The user's interaction quality with the platform interface, including filtering, search, recommendations, in-app customer service, and process fluency	5	Larivière et al. (2017); Chattaraman et al. (2012); Huang & Benyoucef (2013); Tarafdar et al. (2019)
Service-quality perception (MED)	The user's overall cognitive evaluation of platform performance across packaging, freshness, after-sales responsiveness, security, and tailored offerings	5	Parasuraman et al. (1988); Kim & Yum (2024); Monoarfa et al. (2024); Huang & Benyoucef (2013)
Continuance intention (DV)	The user's intention to keep purchasing fresh groceries from the platform, prefer it over alternatives, recommend it, and treat it as a primary channel	5	Bhattacharjee (2001); Gao et al. (2015); Kim & Yum (2024); Monoarfa et al. (2024)
Technology-related apprehension (MODV)	A user's discomfort, nervousness, or unease in interacting with platform technology, new features, and data-privacy considerations	5	Meuter et al. (2003); Tarhini et al. (2021); Tarafdar et al. (2019)

Note. Items = number of measurement items per construct. Sources are the principal instruments from which items were adapted and contextualised to the fresh-grocery setting. Full item wording is provided in Appendix A.

We expect H3b to receive the strongest support because information seeking is the strand most cognitively demanding of platform-system fluency. The other three hypotheses are stated with directional priors but with weaker expected magnitudes.

Research Design

Philosophical orientation and approach

The investigation adopts a positivist orientation, on the grounds that the constructs of interest are measurable, the relationships among them are amenable to statistical estimation, and the theoretical framework (S-O-R, with SERVQUAL as the perceptual mediator) generates falsifiable predictions. This stance is consonant with recent methodological guidance for quantitative research in digital-commerce contexts. Consistent with established PLS-SEM guidance (Hair et al., 2022), partial-least-squares structural equation modelling (PLS-SEM) was elected over covariance-based SEM for four reasons: **1)** the model is structurally complex, with multiple latent constructs, a mediator, and four interaction terms; **2)** PLS-SEM is prediction-oriented, aligning with the study's emphasis on explaining variance in continuance intention; **3)** PLS-SEM is robust to non-normal data, common in survey work on perceptions; and **4)** it accommodates exploratory model extensions of the kind we propose here.

Equations (1) and (2) specify the estimated structural model. In Equation (1), service-quality perception (MED) is regressed on the four engagement dimensions (IV_k , $k = 1-4$: task cognition, information seeking, effort expenditure, human-computer interaction), technology-related apprehension (MODV), and the four latent interaction terms (MODV ×

IV_k); β_k are the engagement path coefficients, β_m the direct apprehension effect, γ_k the moderation coefficients, and ε_1 the disturbance. In Equation (2), continuance intention (DV) is regressed on service-quality perception (β) and, through the direct paths, on the four engagement dimensions (δ_k), with disturbance ε_2 .

$$MED = \sum_{k=1}^4 \beta_k IV_k + \beta_m MODV + \sum_{k=1}^4 \gamma_k (MODV \times IV_k) + \varepsilon_1 \quad (1)$$

$$DV = \beta MED + \sum_{k=1}^4 \delta_k IV_k + \varepsilon_2 \quad (2)$$

Population, sampling, and sample size

The target population was operationalised as active fresh-grocery e-commerce users in Guangdong Province, defined by four jointly applied screening criteria: **a)** experience with platforms that deliver perishable groceries (vegetables, fruit, meat, seafood, dairy); **b)** at least one fresh-grocery purchase in the preceding six months; **c)** a baseline purchase frequency of at least once per month; and **d)** evidence of at least one form of engagement behaviour (information seeking, effort expenditure, human-computer interaction, or feedback provision).

The effective target population, after these criteria are applied, was estimated at 25-35 million users (against a provincial fresh-grocery user base of 40-50 million and a national base exceeding 450 million). Sample-size determination proceeded through three triangulating logics. The "10-times rule" implied a floor of 200-300 cases given the complexity of the structural model; the Krejcie-Morgan table implied a floor of roughly 384 for large populations; and statis-

Table 2 | Pre-test results by item: content-validity ratio, factor loading, item-total correlation, and comprehensibility (n = 40)

Construct	Item	CVR	Loading	Item-total	Understand
Task cognition (WC)	WC1	0.87	0.741	0.576	4.6
	WC2	0.85	0.855	0.582	4.5
	WC3	0.86	0.924	0.718	4.4
	WC4	0.88	0.910	0.719	4.7
	WC5	0.84	0.669	0.738	4.6
Information seeking (IS)	IS1	0.86	0.857	0.610	4.6
	IS2	0.85	0.609	0.376	4.5
	IS3 (R)	0.82	0.880	0.809	4.3
	IS4	0.87	0.670	0.497	4.6
	IS5	0.84	0.780	0.514	4.5
Effort expenditure (EF)	EF1	0.85	0.619	0.489	4.5
	EF2	0.83	0.486	0.561	4.4
	EF3	0.82	0.662	0.560	4.3
	EF4	0.81	0.740	0.439	4.2
	EF5	0.84	0.811	0.520	4.5
Human-computer interaction (HCI)	HCI1	0.86	0.924	0.699	4.7
	HCI2	0.85	0.673	0.721	4.6
	HCI3 (R)	0.82	0.834	0.735	4.3
	HCI4	0.84	0.787	0.328	4.5
	HCI5	0.88	0.526	0.397	4.7
Service-quality perception (SQ)	SQ1	0.87	0.568	0.322	4.7
	SQ2	0.88	0.750	0.680	4.8
	SQ3	0.86	0.582	0.420	4.6
	SQ4	0.85	0.523	0.460	4.6
	SQ5	0.84	0.671	0.517	4.5
Continuance intention (CI)	CI1	0.89	0.625	0.466	4.8
	CI2	0.87	0.601	0.567	4.7
	CI3	0.88	0.898	0.701	4.8
	CI4	0.86	0.758	0.561	4.6
	CI5	0.85	0.722	0.507	4.6
Technology-related apprehension (TA)	TA1	0.86	-0.810	0.508	4.6
	TA2	0.85	-0.791	0.543	4.5
	TA3	0.88	-0.886	0.426	4.7
	TA4 (R)	0.82	-0.862	0.334	4.3
	TA5	0.87	-0.905	0.548	4.6

Notes. (R) denotes reverse-coded items; negative loadings on TA items reflect the reverse-coded construct direction. Acceptance thresholds: CVR > 0.80, |loading| > 0.50, item-total > 0.30, understandability > 4.0. n = 40.

tical-power considerations for detecting interaction effects implied a further increment. After allowing for typical 10-20% post-cleaning loss, the targeted sample size was set at 600. After data cleaning, 550 valid cases were retained.

A combined purposive-convenience sampling approach was used. Purposive sampling ensured that respondents met the four screening criteria; convenience sampling allowed efficient online recruitment via social-media platforms and digital communities frequented by fresh-grocery users. Several procedures, IP and device tracking, minimum response-time thresholds, and consistency checks against reverse-coded items, were applied during fieldwork to protect data integrity. Because recruitment combined purposive screening with convenience-based online channels, the resulting sample is non-probabilistic; we therefore treat it as analytically useful for testing structural relationships rather than as statistically representative of the entire fresh-gro-

cery user population in Guangdong, and we qualify all generalisation claims accordingly.

Instrument and measurement

All latent variables were measured with multi-item scales adapted from validated prior instruments and contextualised to the fresh-grocery setting. Items were rated on a five-point Likert scale from 1 ("strongly disagree") to 5 ("strongly agree"). The five-point format was chosen for its established discriminability and respondent-friendliness in consumer-perception research. [Table 1](#) summarises the construct definitions, the sub-dimensions tapped by each item set, and the principal sources from which each item set was adapted.

Pre-test and pilot test

Two pre-fieldwork stages refined the instrument. A pre-test assessed semantic clarity, construct alignment, and con-

Table 3 | Pilot-test reliability statistics by construct (n = 40)

Construct	Cronbach's alpha	Items meeting (all criteria)	Action taken
Task cognition (WC)	0.807	5/5	All items retained
Information seeking (IS)	0.801	5/5	All items retained
Effort expenditure (EF)	0.776	4/5	EF2 retained after triangulation
Human-computer interaction (HCI)	0.853	5/5	All items retained
Service-quality perception (SQ)	0.792	5/5	All items retained
Continuance intention (CI)	0.838	5/5	All items retained
Technology-related apprehension (TA)	0.929	5/5	All items retained

Note. α = Cronbach's alpha. EF2 was retained after triangulation against its item-total correlation and content validity. n = 40.

Table 4 | Missing-data audit by measurement item-set (n = 550 respondents, 35 items in total)

Item-set	Items	Cases	Missing	Missing rate (%)
Task cognition (IV01-Q1 to Q5)	5	550	0	0.0
Information seeking (IV02-Q1 to Q5)	5	550	0	0.0
Effort expenditure (IV03-Q1 to Q5)	5	550	0	0.0
Human-computer interaction (IV04-Q1 to Q5)	5	550	0	0.0
Service-quality perception (MED-Q1 to Q5)	5	550	0	0.0
Continuance intention (DV-Q1 to Q5)	5	550	0	0.0
Technology-related apprehension (MODV-Q1 to Q5)	5	550	0	0.0

Note. Missing rate = missing cases / 550. No imputation was required. Source: authors' data audit.

textual fit against four benchmarks: content validity ratio (CVR > 0.80), factor loadings ($|\lambda| > 0.50$), item-total correlations (> 0.30), and comprehensibility scores (mean > 4.0 on a five-point understandability scale). Expert reviews and respondent debriefs led to several revisions: ambiguous wording was simplified, double-barrelled items were split, redundant items were removed, and context-specific terms (e.g., "delivery time-slot," "freshness inspection") were introduced. A pilot test with 40 respondents then assessed reliability (Cronbach's alpha > 0.70; CR > 0.70), convergent validity (loadings > 0.50; AVE > 0.50), discriminant clarity, and operational feasibility. [Table 2](#) and [Table 3](#) report the pre-test and pilot-test results respectively.

Data-collection procedure and ethical safeguards

Questionnaires were distributed online over a continuous multi-week fieldwork window. Screening questions enforced the four eligibility criteria at the front of the survey. Continuous monitoring detected uneven regional representation (rebalanced through targeted channel adjustments), repeated devices, anomalously short completion times, and uniform-response (straight-lining) patterns. Of the 600 responses collected, 50 (8.3%) were removed, for duplicate IP/device fingerprints, completion times below one-third of the median time, straight-lining across reverse-coded items, or failed embedded consistency checks, leaving 550 valid cases. The retained sample spanned core Pearl River Delta cities (60.0%), non-core Delta cities (25.1%), and eastern, western, and northern Guangdong (14.9%); its gender split was 52.0% female and 48.0% male.

The present manuscript draws on the same Guangdong survey (N = 550) and structural model previously reported

by Yue et al. (2026); it is presented here as an expanded methodological and interpretive account, not as an independent sample or replication. Relative to that report, this manuscript clarifies the umbrella status of co-productive engagement, provides fuller direct, indirect, total-effect and robustness reporting, adds the simple-slope analysis, and supplies the complete instrument in Appendix A.

The study followed the World Medical Association's Declaration of Helsinki (2013) and complied with both China's Personal Information Protection Law (2021) and the EU General Data Protection Regulation. A digital informed-consent mechanism appeared on the first page of the survey, identifying the study's purpose, the nature of the data collected, the anonymity and voluntariness of participation, and the right to withdraw without penalty. No personally identifying information was captured. Data were transmitted via SSL-encrypted channels and stored on access-controlled, password-protected systems; data retention was capped at three years post-publication. Third-party recruitment platforms were ISO 27001-certified. An optional, segregated email field allowed respondents to request a results summary without compromising anonymity.

Results

Sample profile

After cleaning, the analytical sample comprised 550 respondents. Demographic and behavioural profiles are visualised in [Figure 2](#) through [Figure 8](#): gender, age, education, city-tier, most-frequently-used platform, purchase frequency, and average monthly spend each followed reasonable empirical distributions for the target population.

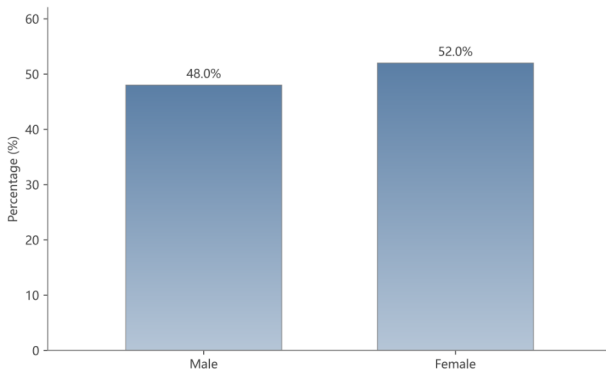


Figure 2 | Gender distribution of respondents (n = 550)

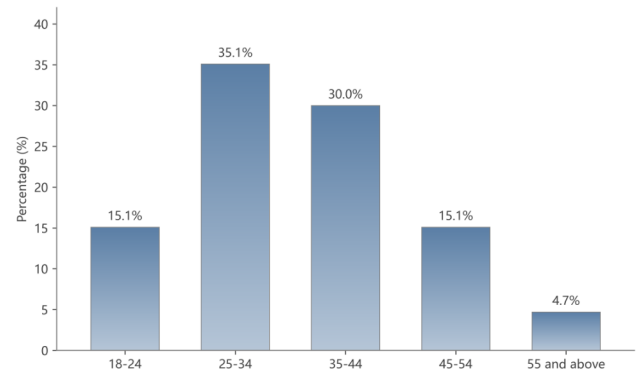


Figure 3 | Age distribution of respondents (n = 550)

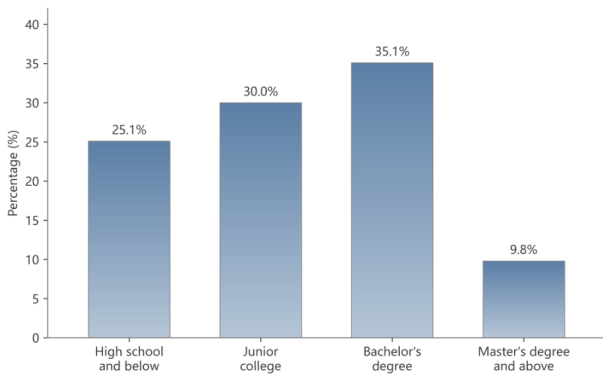


Figure 4 | Educational-attainment distribution of respondents (n = 550)

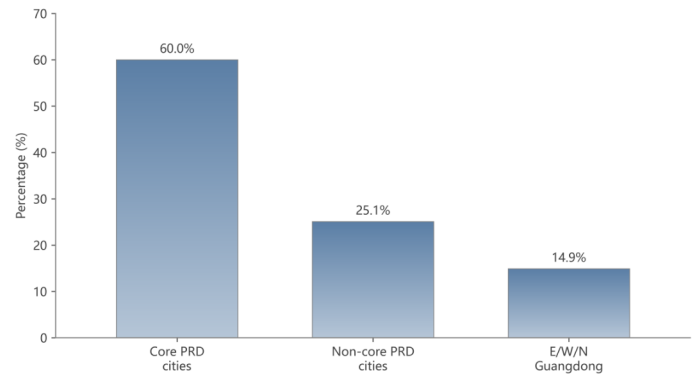


Figure 5 | Long-term residential city classification of respondents (n = 550)

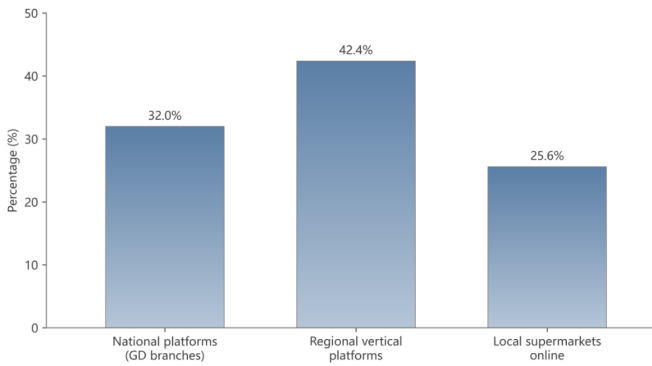


Figure 6 | Distribution of the most frequently used fresh-grocery e-commerce platform (n = 550)

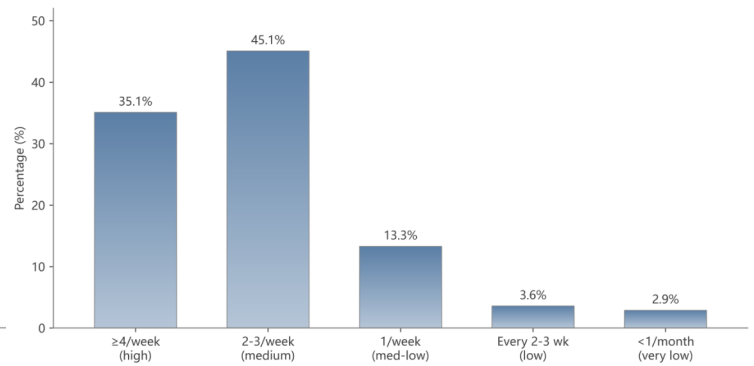


Figure 7 | Purchase frequency on the most frequently used fresh-grocery platform (n = 550)

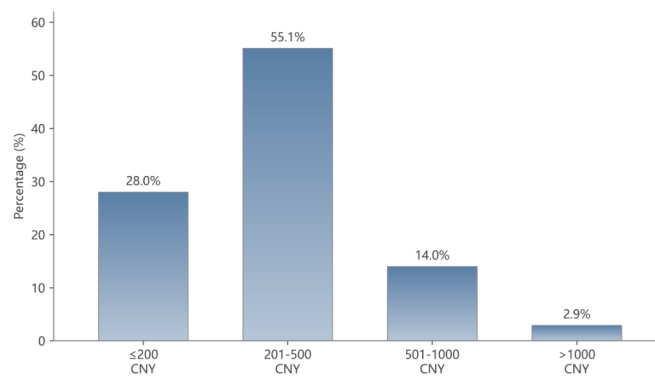


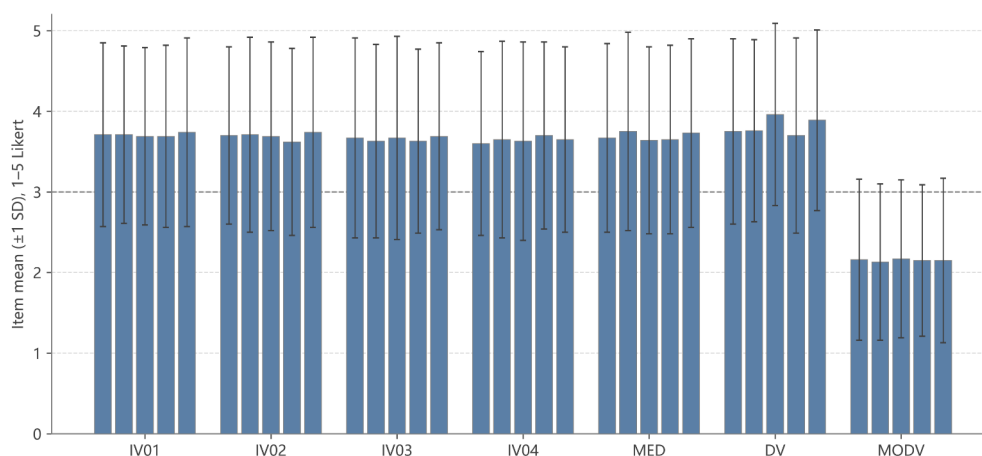
Figure 8 | Average monthly spending on fresh-grocery e-commerce (n = 550)

Table 5 | Descriptive statistics and normality diagnostics by item (n = 550). All items rated 1–5 Likert

Item	Min	Max	Mean	Median	SD	Skewness	Kurtosis
IV01-Q1	1.00	5.00	3.71	4	1.14	-0.74	0.07
IV01-Q2	1.00	5.00	3.71	4	1.10	-0.76	0.04
IV01-Q3	1.00	5.00	3.69	4	1.10	-0.76	0.08
IV01-Q4	1.00	5.00	3.69	4	1.13	-0.75	-0.05
IV01-Q5	1.00	5.00	3.74	4	1.17	-0.73	-0.26
IV02-Q1	1.00	5.00	3.70	4	1.10	-0.81	0.19
IV02-Q2	1.00	5.00	3.71	4	1.21	-0.77	-0.28
IV02-Q3	1.00	5.00	3.69	4	1.17	-0.89	0.09
IV02-Q4	1.00	5.00	3.62	4	1.16	-0.79	-0.05
IV02-Q5	1.00	5.00	3.74	4	1.18	-0.85	-0.02
IV03-Q1	1.00	5.00	3.67	4	1.24	-0.83	-0.20
IV03-Q2	1.00	5.00	3.63	4	1.20	-0.65	-0.43
IV03-Q3	1.00	5.00	3.67	4	1.26	-0.81	-0.29
IV03-Q4	1.00	5.00	3.63	4	1.14	-0.71	-0.08
IV03-Q5	1.00	5.00	3.69	4	1.16	-0.82	0.01
IV04-Q1	1.00	5.00	3.60	4	1.14	-0.69	-0.17
IV04-Q2	1.00	5.00	3.65	4	1.22	-0.77	-0.31
IV04-Q3	1.00	5.00	3.63	4	1.23	-0.69	-0.45
IV04-Q4	1.00	5.00	3.70	4	1.16	-0.85	-0.01
IV04-Q5	1.00	5.00	3.65	4	1.15	-0.69	-0.20

Item	Min	Max	Mean	Median	SD	Skewness	Kurtosis
MED-Q1	1.00	5.00	3.67	4	1.17	-0.76	-0.16
MED-Q2	1.00	5.00	3.75	4	1.23	-0.85	-0.19
MED-Q3	1.00	5.00	3.64	4	1.16	-0.76	-0.05
MED-Q4	1.00	5.00	3.65	4	1.17	-0.81	-0.07
MED-Q5	1.00	5.00	3.73	4	1.17	-0.82	-0.12
DV-Q1	1.00	5.00	3.75	4	1.15	-0.74	-0.20
DV-Q2	1.00	5.00	3.76	4	1.13	-0.72	-0.26
DV-Q3	1.00	5.00	3.96	4	1.13	-1.01	0.24
DV-Q4	1.00	5.00	3.70	4	1.21	-0.76	-0.33
DV-Q5	1.00	5.00	3.89	4	1.12	-0.93	0.16
MODV-Q1	1.00	5.00	2.16	2	1.00	1.23	1.42
MODV-Q2	1.00	5.00	2.13	2	0.97	1.24	1.62
MODV-Q3	1.00	5.00	2.17	2	0.98	1.16	1.31
MODV-Q4	1.00	5.00	2.15	2	0.94	1.33	1.93
MODV-Q5	1.00	5.00	2.15	2	1.02	1.23	1.25

Note. The corrected continuance-intention (DV) rows replace values that, in the previously submitted version, had been transcribed from the information-seeking (IV02) item-set. The mean/skewness asymmetry between IV/MED/DV items (left-skewed, positive evaluations) and MODV items (right-skewed, low apprehension on average) is theoretically expected. n = 550.

**Figure 9 | Item-level means (± 1 SD) across the 35 indicators, grouped by construct; the dashed line marks the 3.0 scale mid-point**

Data preparation

Missing-value analysis indicated 0% missingness across all measurement items; consequently no imputation was required (Table 4). Outlier detection combined Z-score screening ($|Z| > 3$) with boxplot inspection; no extreme cases were identified that warranted exclusion. Reverse-coded items (notably within the technology-related apprehension and selected information-seeking and human-computer interaction items) were recoded to ensure uniform directionality. Distributional inspection produced item-level skewness values mostly in the range -1.08 to -0.65 for the four IV, mediator, and DV item sets and reverse-direction values around +1.16 to +1.34 for the MODV items, with kurtosis values close to zero (Table 5). Although Kolmogorov-Smirnov tests rejected the null of strict normality, the devia-

tions are modest, and the use of PLS-SEM does not require strict normality.

Figure 9 profiles the item-level means with ± 1 SD. The four engagement dimensions, the mediator, and the dependent construct cluster above the scale mid-point (means ≈ 3.6 – 3.9), whereas the technology-related-apprehension items sit well below it (means ≈ 2.1), consistent with a sample of experienced, low-apprehension users.

Figure 10 provides a normality check: histograms of the seven construct composites with a normal reference curve. The four engagement dimensions, the mediator, and the dependent construct are mildly left-skewed, whereas technology-related apprehension is right-skewed; all departures are modest, consistent with the skewness and kurtosis reported in Table 5 and with the use of PLS-SEM, which does not require multivariate normality.

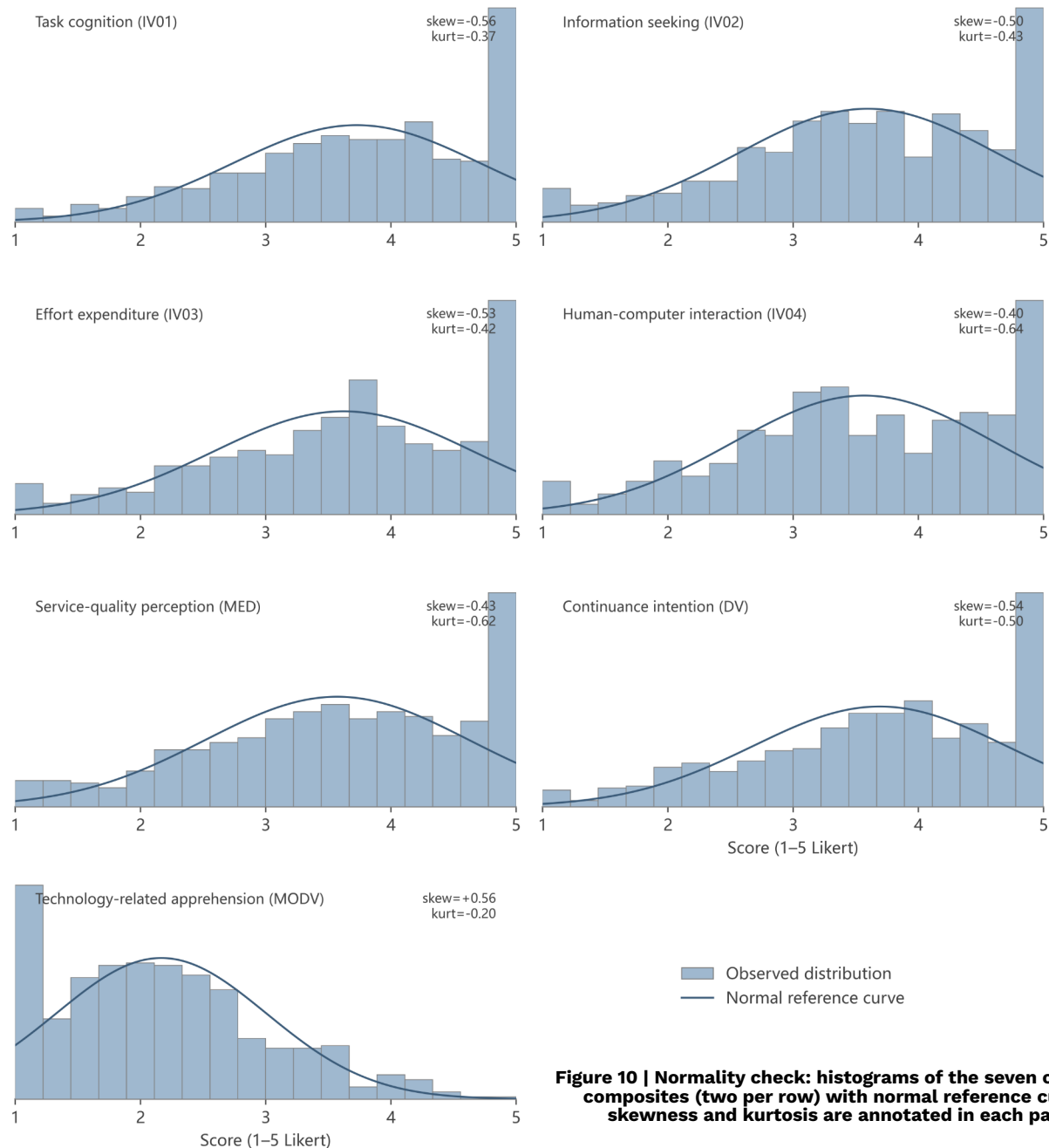


Figure 10 | Normality check: histograms of the seven construct composites (two per row) with normal reference curves; skewness and kurtosis are annotated in each panel

Common-method bias and multicollinearity

To assess the possibility that common-method variance had artificially inflated the inter-construct correlations, an unrotated principal-axis extraction was used to implement Harman's single-factor test. Seven factors emerged with eigenvalues above 1.0, and the first factor accounted for 27.36% of the total variance - well below the conventional 40% (and the more conservative 50%) cutoff (Table 6). The seven-factor cumulative variance reached 66.13%. We therefore concluded that common-method bias is unlikely to drive the substantive results.

Variance inflation factors (VIF) for all 35 indicators ranged from 1.376 (IV01-Q3) to 2.650 (MODV-Q5), all well below the conservative 3.3 ceiling and the more permissive 5.0 ceiling (Table 7), confirming that multicollinearity does not threaten parameter stability.

Because Harman's single-factor test offers only limited evidence, we applied the full-collinearity assessment proposed by Kock (2015), in which each latent construct is regressed on all the other constructs and the resulting variance inflation factors are inspected. All full-collinearity VIFs were below the 3.3 threshold (maximum 2.65), which provides no indication of pathological collinearity or substantial

Table 6 | Harman's single-factor test: extracted components and explained variance

Component	Eigenvalue	% of variance	Cumulative %
1	9.575	27.36	27.36
2	3.688	10.54	37.89
3	2.317	6.62	44.52
4	2.067	5.90	50.42
5	1.919	5.48	55.90
6	1.813	5.18	61.08
7	1.767	5.05	66.13
8	0.987	2.82	68.95
9-35	< 0.611 each	< 1.75 each	100.00

Note. Unrotated principal-axis extraction; the first factor explains 27.36% (< 40% threshold). n = 550.

Table 7 | Indicator-level variance inflation factors across the seven latent constructs

Indicator	VIF	Indicator	VIF	Indicator	VIF
DV-Q1	2.008	IV03-Q1	1.764	MED-Q1	1.908
DV-Q2	2.045	IV03-Q2	1.969	MED-Q2	2.090
DV-Q3	1.908	IV03-Q3	2.051	MED-Q3	2.065
DV-Q4	1.891	IV03-Q4	1.932	MED-Q4	2.035
DV-Q5	2.015	IV03-Q5	2.108	MED-Q5	1.867
IV01-Q1	1.963	IV04-Q1	2.429	MODV-Q1	2.493
IV01-Q2	1.993	IV04-Q2	2.040	MODV-Q2	2.393
IV01-Q3	1.376	IV04-Q3	2.135	MODV-Q3	2.258
IV01-Q4	2.005	IV04-Q4	1.989	MODV-Q4	2.334
IV01-Q5	2.103	IV04-Q5	2.010	MODV-Q5	2.650
IV02-Q1	1.901	\	\	\	\
IV02-Q2	1.889	\	\	\	\
IV02-Q3	1.862	\	\	\	\
IV02-Q4	2.004	\	\	\	\
IV02-Q5	1.728	\	\	\	\

Note. Outer-model (indicator) VIFs; all values are below the conservative 3.3 ceiling. n = 550.

Table 8 | SPSS-derived Cronbach's alpha and item-deletion diagnostics

Construct	Overall alpha	Alpha-if-deleted range across items
Task cognition (IV01)	0.779	0.728 - 0.781
Information seeking (IV02)	0.860	0.812 - 0.851
Effort expenditure (IV03)	0.870	0.831 - 0.861
Human-computer interaction (IV04)	0.885	0.852 - 0.879
Service-quality perception (MED)	0.873	0.839 - 0.868
Continuance intention (DV)	0.873	0.841 - 0.869
Technology-related apprehension (MODV)	0.904	0.875 - 0.897

Note. Alpha-if-deleted ranges replace the previously submitted values, which were uniform across constructs in error; in every construct, deleting any single item does not raise alpha above the overall coefficient, so all items are retained. n = 550.

Table 9 | Bootstrap composite reliability (ρ_c) from SmartPLS 4.1.1 (5,000 resamples)

Construct	Bootstrap alpha	ρ_c	T (ρ_c)	p (ρ_c)
Continuance intention (DV)	0.873	0.908	180.90	0.000
Task cognition (IV01)	0.876	0.892	155.53	0.000
Information seeking (IV02)	0.861	0.899	166.26	0.000
Effort expenditure (IV03)	0.872	0.906	162.08	0.000
Human-computer interaction (IV04)	0.885	0.916	231.88	0.000
Service-quality perception (MED)	0.877	0.908	195.48	0.000
Technology-related apprehension (MODV)	0.907	0.929	212.55	0.000

Note. ρ_c = composite reliability; T and p from 5,000 bootstrap resamples. n = 550.

common-method bias under this diagnostic. Because all constructs were nonetheless measured from the same respondents on a single occasion, we retain common-method variance as a residual limitation rather than treating it as fully excluded.

Measurement-model evaluation

Construct reliability was excellent across all seven constructs (Table 8 and Table 9). SPSS-derived Cronbach's alpha coefficients ranged from 0.779 (task cognition) to 0.904 (technology-related apprehension), all above the 0.70 acceptance threshold. SmartPLS bootstrap estimates generated

highly significant T-values (all $p < 0.001$) and ranged from 0.861 to 0.907. Composite reliability (ρ_c) for each latent construct ranged from 0.892 to 0.929, all well above the 0.70 baseline.

Figure 11 plots the outer (indicator) loadings for all seven constructs. Every indicator exceeds the 0.708 benchmark except IV01-Q3 (0.617), which is discussed below; Figure 12 summarises Cronbach's alpha and composite reliability against the 0.70 threshold.

Discriminant validity was evaluated using the hetero-trait-monotrait (HTMT) ratio with bootstrap-derived 95% confidence intervals (Table 10). The largest HTMT was

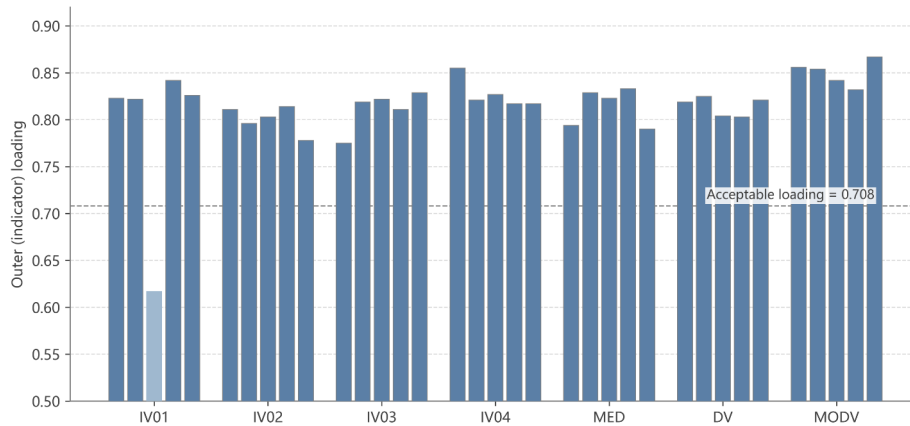


Figure 11 | Outer (indicator) loadings for the seven constructs. The dashed line marks the 0.708 acceptance benchmark; IV01-Q3 (0.617, hatched) is the only sub-benchmark indicator and is retained on content and item-total grounds.

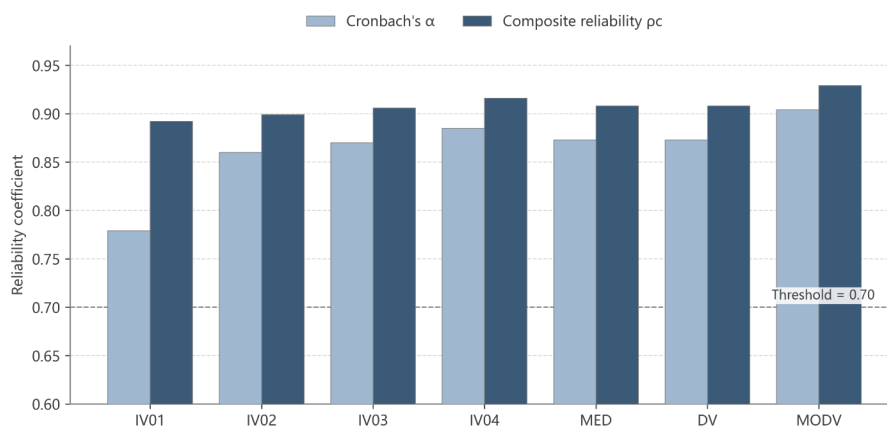


Figure 12 | Cronbach's alpha and composite reliability (ρ_c) by construct, against the 0.70 acceptance threshold

0.505 (IV03 to DV), comfortably below the 0.85 threshold; upper confidence-interval bounds never approached 1.0 (the highest was 0.596). HTMTs involving the moderator were uniformly low (0.075-0.324), confirming its conceptual independence from the other constructs.

Figure 13 displays the same HTMT ratios as a heat map.

Sampling-adequacy testing supported the measurement structure further. The Kaiser-Meyer-Olkin statistic was 0.921 (well above the 0.90 "excellent" threshold) and Bartlett's test of sphericity was highly significant ($\chi^2 = 9939.146$, $df = 595$, $p < 0.001$), summarised in **Table 11**. Exploratory factor analysis with varimax rotation extracted seven factors with eigenvalues above 1.0, accounting for 66.13% of variance jointly (**Table 12**); each measurement item loaded strongly on its intended factor (**Table 13** condenses the post-rotation loading profile).

Figure 14 presents the scree plot; the eigenvalues elbow after the seventh component, and seven factors satisfy the Kaiser (eigenvalue > 1) criterion.

Because the continuance-intention scale combines continued-use, preference, recommendation, and primary-channel items, we verified that these behavioural-intention facets form a single coherent construct. The five items load

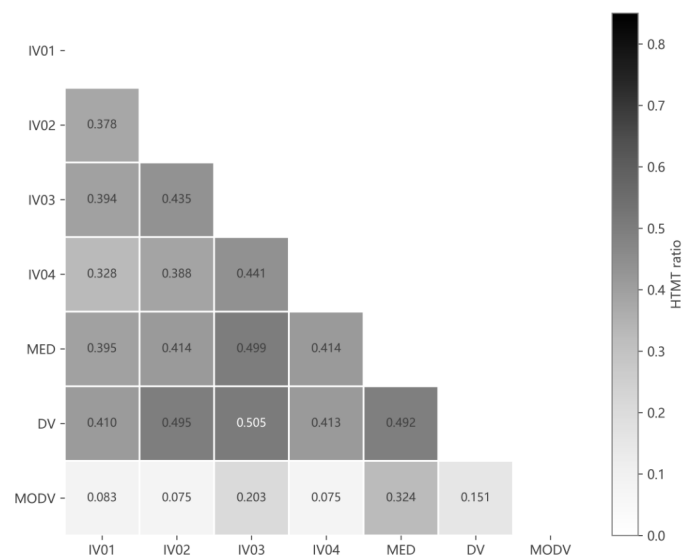


Figure 13 | Heterotrait-monotrait (HTMT) ratios among the seven constructs (lower triangle); all values are below the 0.85 threshold.

Table 10 | Heterotrait-monotrait (HTMT) ratios with 95% bootstrap confidence intervals (5,000 resamples)

Construct pair	HTMT	2.5% CI	97.5% CI
IV01 - DV	0.410	0.307	0.511
IV02 - DV	0.495	0.394	0.587
IV02 - IV01	0.378	0.276	0.479
IV03 - DV	0.505	0.408	0.596
IV03 - IV01	0.394	0.295	0.494
IV03 - IV02	0.435	0.331	0.535
IV04 - DV	0.413	0.315	0.513
IV04 - IV01	0.328	0.229	0.429
IV04 - IV02	0.388	0.285	0.486
IV04 - IV03	0.441	0.341	0.537
MED - DV	0.492	0.388	0.592
MED - IV01	0.395	0.293	0.490
MED - IV02	0.414	0.313	0.510
MED - IV03	0.499	0.402	0.594
MED - IV04	0.414	0.314	0.511
MODV - DV	0.151	0.060	0.258
MODV - IV01	0.083	0.042	0.182
MODV - IV02	0.075	0.048	0.175
MODV - IV03	0.203	0.095	0.313
MODV - IV04	0.075	0.059	0.159
MODV - MED	0.324	0.224	0.425

Note. All HTMT ratios are below the 0.85 threshold and no upper CI bound approaches 1.0, supporting discriminant validity (Henseler et al., 2015). n = 550.

Table 12 | Total variance explained by the seven-factor solution (initial and rotation sums).

Component	Initial eigenvalue	% var.	Cumul. %	Rot. eigenvalue	Rot. % var.	Rot. cumul. %
1	9.575	27.36	27.36	3.670	10.49	10.49
2	3.688	10.54	37.89	3.496	9.99	20.48
3	2.317	6.62	44.52	3.320	9.49	29.96
4	2.067	5.90	50.42	3.307	9.45	39.41
5	1.919	5.48	55.90	3.289	9.40	48.81
6	1.813	5.18	61.08	3.242	9.26	58.07
7	1.767	5.05	66.13	2.821	8.06	66.13

Note. Varimax rotation; seven factors with eigenvalues > 1.0 explain 66.13%. n = 550.

Table 11 | Sampling adequacy and sphericity diagnostics

Statistic	Value
Kaiser-Meyer-Olkin measure	0.921
Bartlett's chi-square	9939.146
Degrees of freedom	595
Significance	0.000

Note. KMO = Kaiser-Meyer-Olkin measure; Bartlett's test of sphericity. n = 550.

Table 13 | Condensed post-rotation factor-loading profile (varimax)

Item-set	Loading on intended factor	Highest cross-loading magnitude
IV01-Q1, Q2, Q4, Q5	0.759 - 0.833	≤ 0.16
IV02-Q1 to Q5	0.717 - 0.791	≤ 0.18
IV03-Q1 to Q5	0.718 - 0.795	≤ 0.22
IV04-Q1 to Q5	0.764 - 0.823	≤ 0.17
MED-Q1 to Q5	Strong on Factor 5	≤ 0.17
DV-Q1 to Q5	Strong on Factor 4	≤ 0.16
MODV-Q1 to Q5	Strong negative loadings on Factor 1	≤ 0.07

Note. A factor-loading anomaly on IV01-Q3 (which loaded weakly and inconsistently) was noted; the item was retained on the basis of its acceptable item-total correlation and pre-test CVR, and reliability tests confirm it does not destabilise its construct. n = 550.

Table 14 | Pearson correlations among latent-variable composites (n = 550)

	IV01	IV02	IV03	IV04	MED	DV	MODV
IV01	1						
IV02	0.343**	1					
IV03	0.343**	0.377**	1				
IV04	0.294**	0.340**	0.384**	1			
MED	0.344**	0.357**	0.435**	0.362**	1		
DV	0.372**	0.427**	0.441**	0.362**	0.431**	1	
MODV	-0.073	-0.066	-0.183**	-0.052	-0.287**	-0.135**	1

Note. Pearson correlations among latent-variable composites; ** p < 0.01 (two-tailed). n = 550.

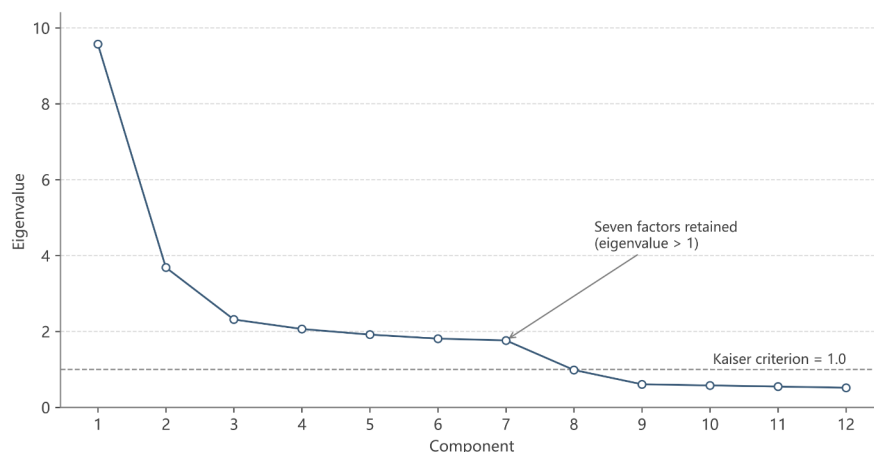
**Figure 14 | Scree plot of component eigenvalues; the dashed line marks the Kaiser criterion (eigenvalue = 1.0), supporting a seven-factor solution.**

Table 15 | Structural-model fit indices (5,000 bootstrap resamples)

Metric	Model	Original sample	Sample mean	95% bound	99% bound
SRMR	Saturated	0.041	0.034	0.037	0.038
SRMR	Estimated	0.041	0.035	0.037	0.039
d_ULS	Saturated	1.061	0.745	0.840	0.893
d_ULS	Estimated	1.055	0.763	0.879	0.948
d_G	Saturated	0.330	0.307	0.334	0.346
d_G	Estimated	0.327	0.304	0.329	0.341

Note. SRMR < 0.08 indicates acceptable approximate fit; d_ULS and d_G are discrepancy measures. 5,000 resamples. n = 550.

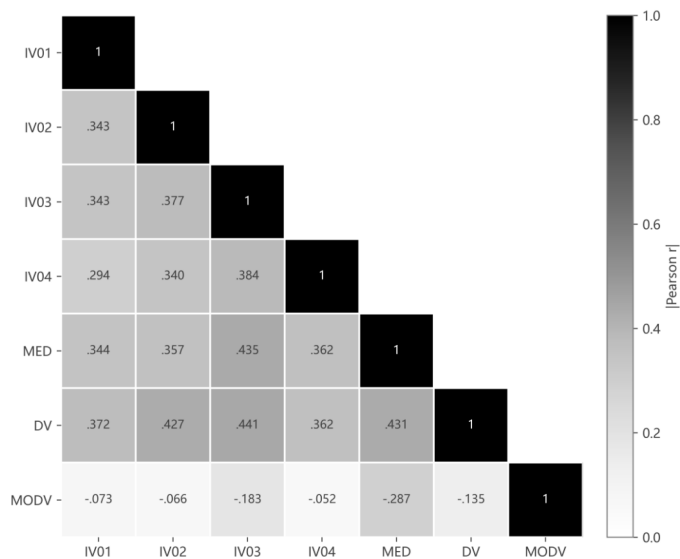


Figure 15 | Pearson correlation matrix among the seven constructs (lower triangle); shade encodes $|r|$ and the signed coefficient is annotated.

Table 16 | Coefficient-of-determination (R-squared) estimates with bootstrap inference

Construct	R-sq (Original)	R-sq (Mean)	SD	T	p
Continuance intention (DV)	0.342	0.352	0.042	8.24	0.000
Service-quality perception (MED)	0.403	0.418	0.037	10.84	0.000

Note. R-squared with 5,000-resample bootstrap inference. n = 550.

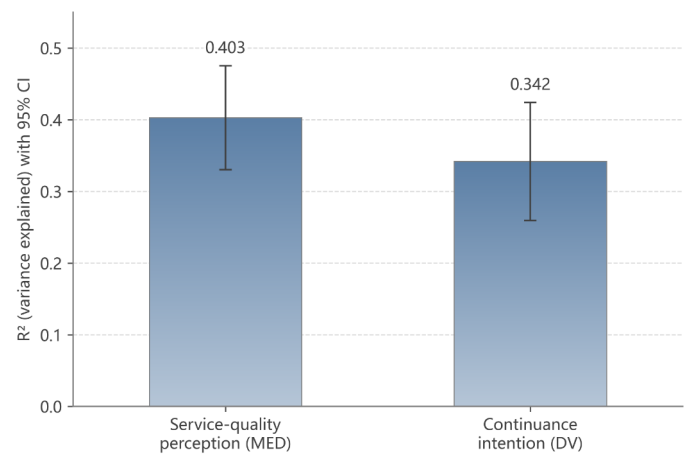


Figure 16 | Coefficient of determination (R^2) for the two endogenous constructs, with 95% confidence intervals.

Figure 15 visualises the correlation matrix as a heat map; the cell shade encodes the absolute correlation and the signed value is annotated, so the uniformly weak negative correlations of technology-related apprehension are visible at a glance.

Structural-model evaluation

Structural-model fit indices fall within recommended ranges (**Table 15**). The SRMR for both saturated and estimated models is 0.041, well under the conservative 0.08 threshold. The geodesic distance (d_G) is 0.327 (estimated model), and the unweighted least-squares discrepancy (d_{ULS}) is 1.055.

R-squared statistics indicate moderate explanatory strength: 40.3% of the variance in service-quality perception and 34.2% of the variance in continuance intention are explained by their respective predictors (**Table 16**). Both R-squared values are significant at $p < 0.001$.

Figure 16 plots the two R^2 values with their 95% confidence intervals; both endogenous constructs show moderate, statistically significant explanatory power.

Effect-size (f-squared) estimates (**Table 17**) are predominantly in the weak-to-small range, with two exceptions: the direct effect of technology-related apprehension on service-quality perception ($f\text{-sq} = 0.114$, approaching medium) and

on a single factor in the exploratory solution (all primary loadings on one factor; cross-loadings ≤ 0.16 ; **Table 13**), with Cronbach's $\alpha = 0.873$, composite reliability $\rho_c = 0.908$, and average variance extracted above 0.50, and the construct is discriminant from all others ($HTMT \leq 0.505$; **Table 10**). We therefore retain continuance intention as a unidimensional construct, consistent with extended expectation-confirmation treatments that bundle repurchase, preference, and advocacy intentions (**Bhattacharjee, 2001**). We nonetheless acknowledge that the recommendation (word-of-mouth) item taps an advocacy facet that future work could model as a separate outcome.

Inter-construct correlation patterns (**Table 14**) align with the hypothesised relations: each engagement strand correlates positively with both service-quality perception and continuance intention; service-quality perception correlates positively with continuance intention; and technology-related apprehension correlates negatively with service-quality perception (-0.287), with effort expenditure (-0.183), and (more weakly) with continuance intention (-0.135).

Table 17 | Effect-size (f-squared) estimates for structural relations and interaction terms

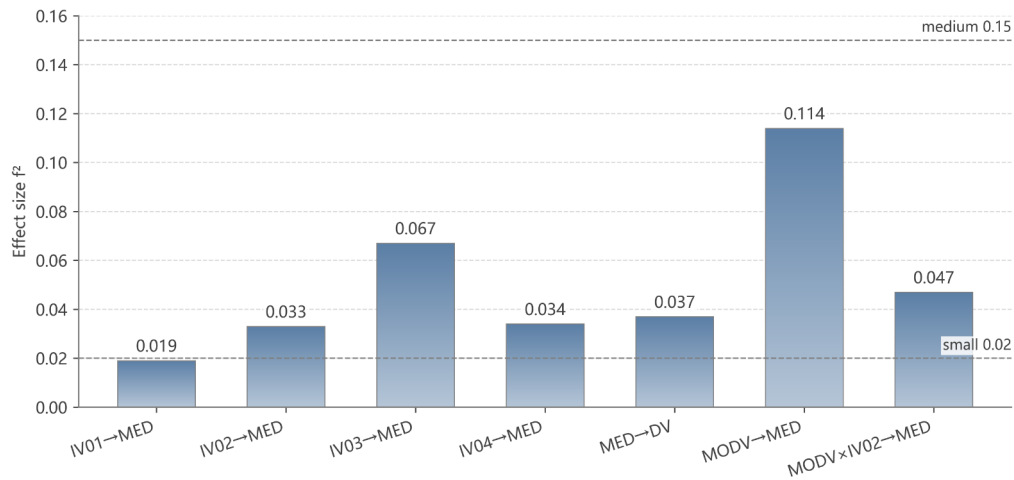
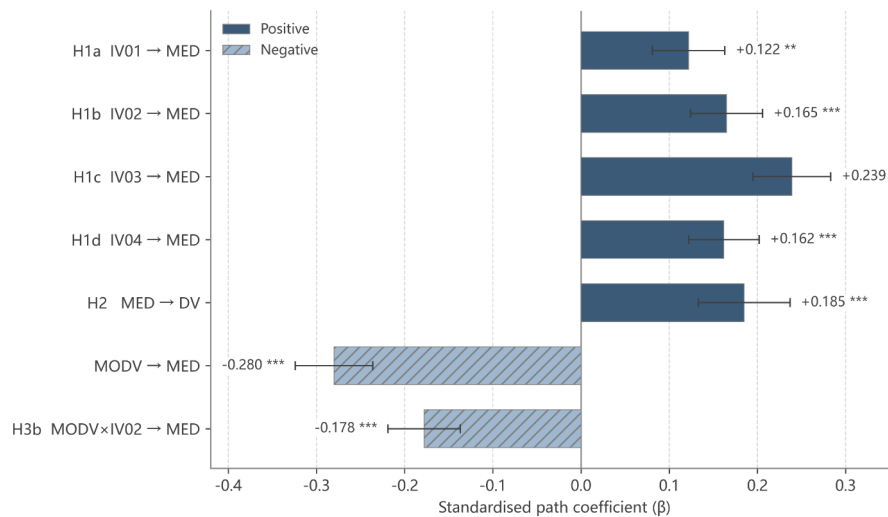
Path	f-sq	T	p
IV01 to DV	0.020	1.42	0.156
IV01 to MED	0.019	1.43	0.153
IV02 to DV	0.051	2.19	0.029
IV02 to MED	0.033	1.97	0.049
IV03 to DV	0.039	1.84	0.066
IV03 to MED	0.067	2.56	0.010
IV04 to DV	0.015	1.25	0.212
IV04 to MED	0.034	1.93	0.054
MED to DV	0.037	1.65	0.099
MODV to MED	0.114	2.89	0.004
MODV x IV01 to MED	0.004	0.47	0.641
MODV x IV02 to MED	0.047	2.09	0.037
MODV x IV03 to MED	0.000	0.00	0.997
MODV x IV04 to MED	0.009	0.84	0.400

Note. Effect sizes f^2 (Equation (3)); 0.02/0.15/0.35 = small/medium/large. The effects are predominantly small, so substantive claims are kept correspondingly measured. $n = 550$.

Table 18 | Structural-model path coefficients with bootstrap inference (5,000 resamples)

Path	Original	Mean	SD	T	p	Decision
IV01 to DV	0.129	0.131	0.042	3.077	0.002	Significant
IV01 to MED (H1a)	0.122	0.121	0.041	3.006	0.003	Supported
IV02 to DV	0.209	0.209	0.046	4.579	0.000	Significant
IV02 to MED (H1b)	0.165	0.165	0.041	4.022	0.000	Supported
IV03 to DV	0.192	0.193	0.049	3.958	0.000	Significant
IV03 to MED (H1c)	0.239	0.239	0.044	5.482	0.000	Supported
IV04 to DV	0.112	0.113	0.042	2.688	0.007	Significant
IV04 to MED (H1d)	0.162	0.162	0.040	4.055	0.000	Supported
MED to DV (H2)	0.185	0.183	0.052	3.530	0.000	Supported
MODV to MED	-0.280	-0.282	0.044	6.385	0.000	Significant
MODV x IV01 to MED (H3a)	-0.052	-0.052	0.047	1.103	0.270	Not supported
MODV x IV02 to MED (H3b)	-0.178	-0.180	0.041	4.381	0.000	Supported
MODV x IV03 to MED (H3c)	-0.004	-0.003	0.048	0.077	0.939	Not supported
MODV x IV04 to MED (H3d)	-0.082	-0.083	0.047	1.761	0.078	Not supported

Note. Standardised path coefficients with 5,000-resample bootstrap inference. * $p < .05$, ** $p < .01$, *** $p < .001$. $n = 550$.

**Figure 17 | Effect sizes (f^2) for the structural relations, against the 0.02 (small) and 0.15 (medium) benchmarks.****Figure 18 | Standardised structural path coefficients with bootstrap standard errors. Positive coefficients are solid, negative coefficients hatched (** $p < .01$, *** $p < .001$)**

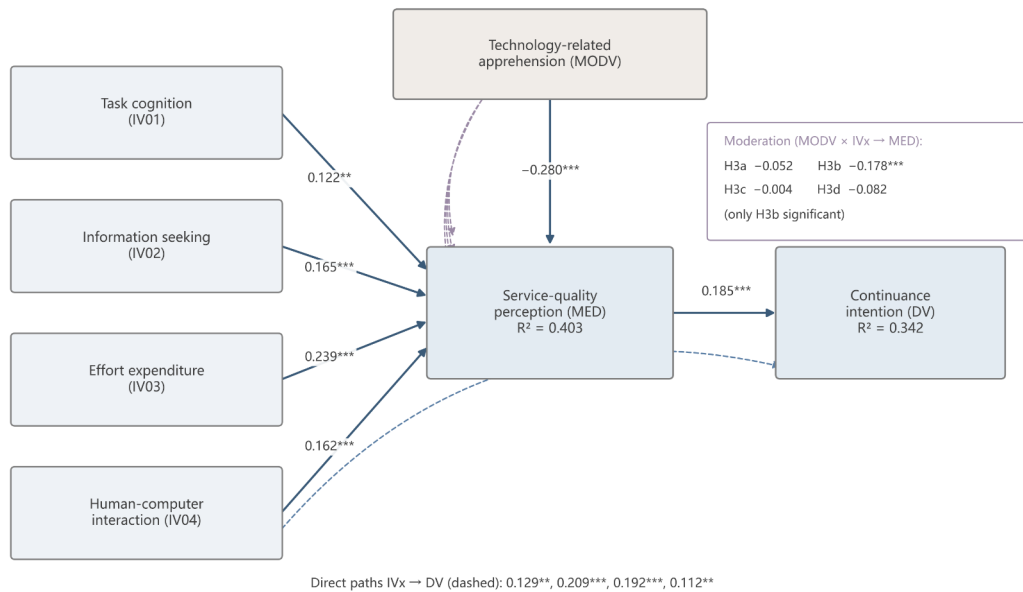


Figure 19 | Structural model with standardised path coefficients, R² for the two endogenous constructs, the direct technology-related-apprehension effect, and the four moderating interaction terms (only H3b significant).
Dashed arrows denote moderation and the additional direct engagement→continuance paths.

Note: ** p < .01, *** p < .001. Solid arrows = hypothesised paths; dashed = moderation and additional direct paths.

the effect of effort expenditure on service-quality perception (f-sq = 0.067). The interaction term MODV by IV02 on MED reaches f-sq = 0.047, a weak but statistically significant moderation.

Effect sizes were computed as f^2 (Equation (3)), where R^2_{incl} and R^2_{excl} are the explained variances of the dependent construct with and without the focal predictor; values of 0.02, 0.15, and 0.35 denote small, medium, and large effects.

$$f^2 = \frac{R^2_{incl} - R^2_{excl}}{1 - R^2_{incl}} \quad (3)$$

Path-coefficient estimates (Table 18) speak directly to the hypotheses. All four engagement strands raised service-quality perception, with the strongest single contribution from effort expenditure (beta = 0.239), followed by information seeking (beta = 0.165), human-computer interaction (beta = 0.162), and task cognition (beta = 0.122). Service-quality perception raised continuance intention (beta = 0.185). Technology-related apprehension exerted a sizable direct depressing effect on service-quality perception (beta = -0.280) and a single significant moderating effect on the information-seeking route (beta = -0.178); the other three moderating effects were directionally negative but not statistically significant. Figure 19 visualises the full structural model.

Mediation analysis

To test the mediating role of perceived service quality directly, rather than inferring it from the pattern of direct paths, we estimated the specific indirect effect of each engagement dimension on continuance intention through service-quality perception. Following the product-of-coefficients approach, the indirect and total effects are defined in Equation (4), where a_k is the engagement→MED path, b the MED→DV path, and c'_k the direct engagement→DV path; the proportion mediated is the indirect effect divided by the total effect. Confidence intervals were obtained from 5,000 resamples of the coefficient distribution, a Monte Carlo / bootstrap approximation that does not assume a normal sampling distribution for the product term (Preacher & Selig, 2012).

$$\text{Indirect}_k = a_k b, \quad \text{Total}_k = c'_k + a_k b \quad (4)$$

All four indirect effects are positive and significant (95% confidence intervals excluding zero), and all four direct effects remain significant. Perceived service quality therefore complementarily but partially mediates the engagement-to-continuance relationships, accounting for approximately 13–21% of each total effect. The largest indirect effect runs through effort expenditure ($a \times b = 0.044$), consistent with its dominant path to service-quality perception.

Table 19 | Specific indirect, direct, and total effects on continuance intention via service-quality perception

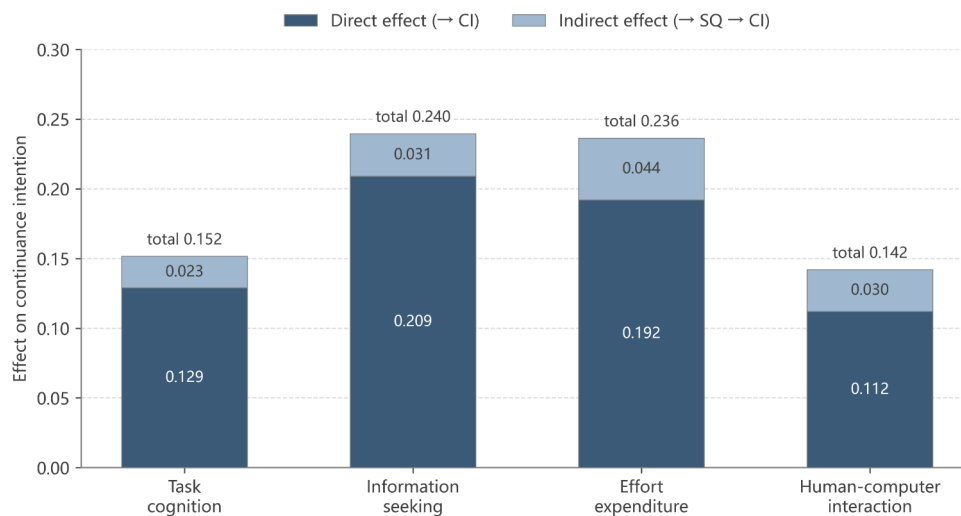
Engagement dimension	Indirect (a×b)	95% CI	Direct (c')	Total	% mediated	Mediation type
Task cognition	0.023	[0.006, 0.045]	0.129	0.152	14.9%	Complementary partial
Information seeking	0.031	[0.011, 0.056]	0.209	0.240	12.7%	Complementary partial
Effort expenditure	0.044	[0.018, 0.077]	0.192	0.236	18.7%	Complementary partial
Human-computer interaction	0.030	[0.011, 0.055]	0.112	0.142	21.1%	Complementary partial

Note. Indirect = a×b; total = c' + a×b (Equation (4)); 95% CIs from 5,000 Monte Carlo / bootstrap resamples (Preacher & Selig, 2012). All indirect effects are positive with CIs excluding zero and all direct effects remain significant, indicating complementary partial mediation. n = 550.

Table 20 | Hypothesis-testing summary

Hypothesis	Statement	beta	p	Outcome
H1a	Task cognition to Service-quality perception	0.122	0.003	Supported
H1b	Information seeking to Service-quality perception	0.165	0.000	Supported
H1c	Effort expenditure to Service-quality perception	0.239	0.000	Supported
H1d	Human-computer interaction to Service-quality perception	0.162	0.000	Supported
H2	Service-quality perception to Continuance intention	0.185	0.000	Supported
H3a	Apprehension moderates Task cognition route	-0.052	0.270	Not supported
H3b	Apprehension moderates Information seeking route	-0.178	0.000	Supported
H3c	Apprehension moderates Effort expenditure route	-0.004	0.939	Not supported
H3d	Apprehension moderates Human-computer interaction route	-0.082	0.078	Not supported
H4a	Task cognition to Continuance intention	0.129	0.002	Supported
H4b	Information seeking to Continuance intention	0.209	0.000	Supported
H4c	Effort expenditure to Continuance intention	0.192	0.000	Supported
H4d	Human-computer interaction to Continuance intention	0.112	0.007	Supported

Note. β = standardised coefficient; p from 5,000 bootstrap resamples. H4a–H4d are the additional direct engagement→continuance paths. n = 550.

**Figure 20 | Decomposition of each engagement dimension's total effect on continuance intention into direct and indirect (via service-quality perception) components.**

Simple-slope analysis of the significant interaction

To interpret the single significant moderation (H3b), we probed the information-seeking × technology-related-apprehension interaction. The simple slope of information seeking on service-quality perception, conditional on apprehension, is given by Equation (5), where β_{IV2} is the information-seeking main effect and γ_2 the interaction coefficient.

$$\frac{\partial \text{MED}}{\partial IV_2} = \beta_{IV2} + \gamma_2 \text{MODV} \quad (5)$$

Figure 21 plots this slope at low (−1 SD), mean, and high (+1 SD) apprehension. The information-seeking slope falls from +0.343 at low apprehension to +0.165 at the mean and to a non-significant −0.013 at high apprehension. Substantively, the quality-enhancing return to information seeking is

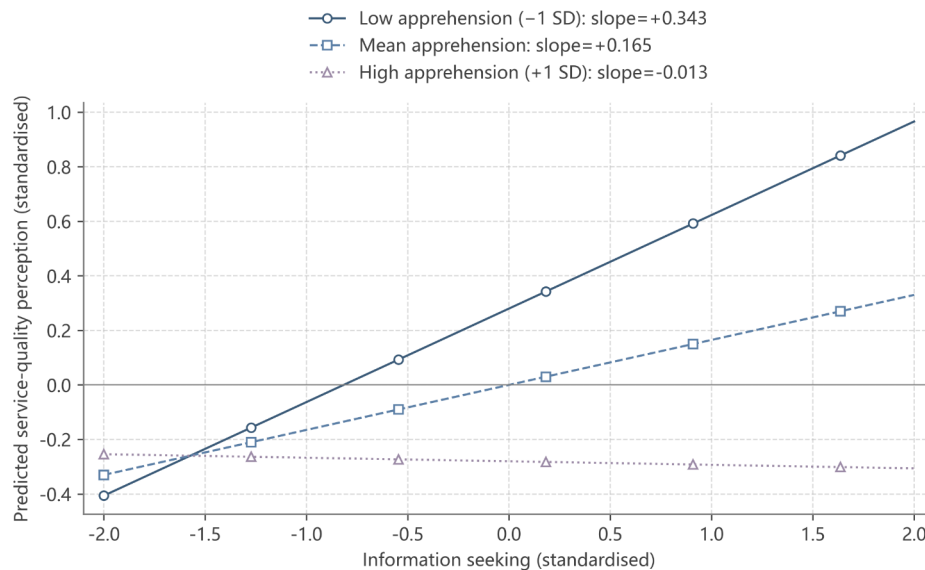


Figure 21 | Simple slopes of information seeking on service-quality perception at low (–1 SD), mean, and high (+1 SD) technology-related apprehension

concentrated among users with low-to-moderate apprehension and effectively disappears for highly apprehensive users. We present this as an empirical finding specific to the present model and sample rather than as a general property of technology-related apprehension.

Hypothesis-testing summary

Of the thirteen hypotheses, ten are supported and three are not (Table 20). The four engagement-to-perception relations (H1a–H1d) and the perception-to-intention link (H2) are all supported, as are the four direct engagement-to-continuance relations (H4a–H4d). Among the four moderation hypotheses, only the information-seeking moderation (H3b) is supported; technology-related apprehension does not significantly dampen the cognitive (H3a), effort (H3c), or interaction (H3d) routes.

Figure 22 summarises the outcome of all thirteen hypotheses, showing each standardised coefficient with its 95% confidence interval and whether it is supported.

Discussion

What the engagement architecture tells us

The clearest empirical signal in the data is that the four engagement strands carry different weights inside the same model. Effort expenditure does the heaviest lifting ($\beta = 0.239$), followed by information seeking, human-computer interaction, and task cognition. That hierarchy is theoretically informative for at least three reasons.

First, the dominance of effort expenditure is consistent with co-production accounts in which the user's own behavioural investment becomes part of the perceived service value (Wu & Chen, 2017; Sadighha et al., 2025). A user who invests time selecting a delivery window, who tolerates a

small product imperfection, who participates in a review programme, is not merely consuming the platform's service but co-producing it. That co-production posture biases the resulting service evaluation upward, because the user has psychological stake in the outcome. Substantively this means that retention strategy in the fresh-grocery channel should not be organised around minimising user effort but around making user effort feel productive – a different objective from the conventional "frictionless commerce" emphasis.

Second, information seeking lands in the middle of the hierarchy. This makes sense given the unusually high pre-purchase uncertainty of perishable goods: a user who reads provenance labels, compares freshness ratings, and parses delivery-slot logistics enters into the purchase with calibrated expectations, but the marginal benefit of additional information seeking diminishes once a baseline of confidence has been reached (Qi et al., 2024; Wang & Li, 2025).

Third, human-computer interaction has a near-equivalent direct effect to information seeking, despite being a property of the platform's design rather than the user's behaviour. This is the strongest evidence in the model that perceived service quality is not merely a function of user behaviour or platform behaviour but of the joint configuration – the same user can experience the same platform very differently depending on the smoothness of filtering, the helpfulness of intelligent search, and the responsiveness of in-app customer service (Tarafdar et al., 2019; Huang & Benyoucef, 2013).

Task cognition is the foundational rather than the dominant strand. Its β of 0.122 is the smallest of the four but still significant. Conceptually, task cognition is best understood as a prerequisite for the other three strands; without it, the user cannot effectively deploy information seeking,

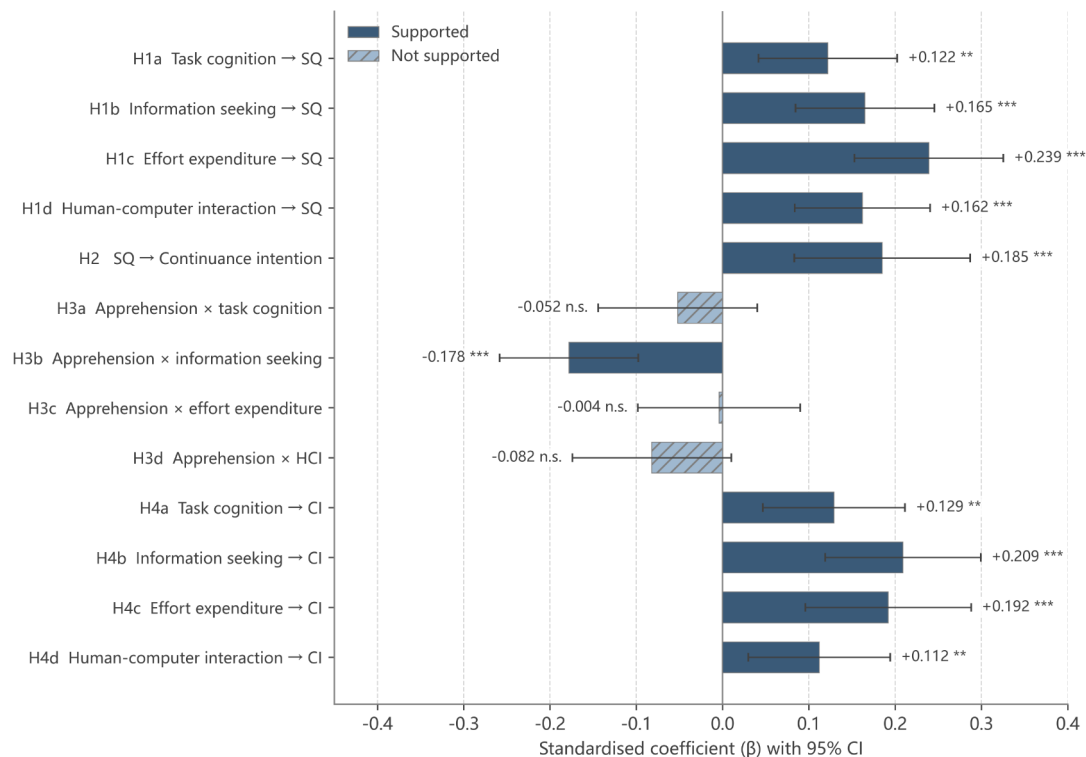


Figure 22 | Outcome of all thirteen hypotheses: standardised coefficients with 95% confidence intervals. Solid bars are supported hypotheses; hatched bars are not supported (* $p < .05$, ** $p < .01$, *** $p < .001$).

cannot calibrate effort, and cannot translate interface design into smooth task completion. A simple test of this interpretation is that the f-squared estimates for the higher-weight strands are concentrated in MED rather than DV, indicating that engagement strands chiefly route through perceived service quality rather than directly through behavioural intention - consistent with the S-O-R logic of the model.

The mediating role of perceived service quality

The H2 result ($\beta = 0.185$, $p < 0.001$) confirms that perceived service quality is the proximate antecedent of continuance intention in this setting. Combined with the four supported H1 paths and the consistent direction of the indirect effects, this constitutes evidence that perceived service quality is the principal route through which engagement reaches retention. Service quality is the organism in the S-O-R chain, and it is a load-bearing organism: even when engagement strands have direct effects on continuance intention, these are best understood as engagement-as-stimulus translating into perception-as-organism translating into intention-as-response.

The substantive implication is that retention strategy cannot bypass service-quality perception. A platform that successfully boosts user effort but fails to convert that effort into perceptible quality (because of inconsistent freshness, irregular delivery times, opaque information, or unresponsive after-sales support) will see the input dissipate. Conversely a platform that consistently delivers high perceived

quality will see retention emerge as the path of least resistance, even when its competitor offers a marginally lower price.

This is also where the SERVQUAL-as-mediator move makes its theoretical contribution. Classical SERVQUAL is descriptive (it measures quality across five dimensions); positioning it as a mediating mechanism makes it explanatory (it identifies the cognitive translation step between engagement and behavioural outcome). Doing so moves SERVQUAL into closer dialogue with behavioural-intention theories ([Monoarfa et al., 2024](#); [Espino-Rodriguez & Rodriguez-Diaz, 2021](#)), and it lets the model produce hypothesis-driven predictions about which engagement design choices will and will not move the retention needle.

Why apprehension moderates only the informational route

The asymmetric moderation result is, within this model, a notable and theoretically suggestive finding. Technology-related apprehension exerts a substantial direct negative effect on service-quality perception ($\beta = -0.280$, $p < 0.001$), confirming the well-established baseline that apprehensive users see the platform less favourably. But the interaction term is significant only for information seeking ($\beta = -0.178$, $p < 0.001$). It is not significant for task cognition, effort expenditure, or human-computer interaction.

We interpret this pattern as follows. Apprehension is a cognitive-affective load. It depresses the user's ability to

process platform-provided information efficiently. Where the engagement strand is itself cognitively demanding - as information seeking is, requiring evaluation, comparison, and integration across multiple information sources - apprehension exerts a measurable dampening influence, because the user simply cannot extract as much quality-relevant signal from the same engagement effort. Where the engagement strand is behavioural rather than cognitive (effort expenditure), or where the strand depends on the platform's design rather than the user's cognitive bandwidth (human-computer interaction), or where the strand pre-supposes rather than generates rule comprehension (task cognition), apprehension's marginal influence is comparatively muted.

This finding has two consequences. Theoretically, it is consistent with, rather than proof of, a path-conditional view, and it qualifies, in this single setting, treatments of technology-related apprehension as a uniformly generalised inhibitor (Tarhini et al., 2021; Tarafdar et al., 2019). Practically, it suggests that apprehension-sensitive design should focus on the informational interface, simplifying search and filtering, providing visual rather than purely textual information, and offering decision-support tools that reduce the cognitive cost of information seeking, rather than on uniformly reducing all engagement demands. Because the interaction effect is modest ($f^2 = 0.047$) and observed in one cross-sectional sample, these interpretations require replication before being generalised.

Direct engagement-to-intention paths

A subsidiary observation is worth noting: the four direct engagement-to-continuance-intention paths are all significant (beta between 0.112 and 0.209). This implies that the mediation through perceived service quality is partial rather than full. Engagement strands have both a routed effect (via perception) and a residual direct effect on intention. The residual direct effect is consistent with habit-formation accounts in which repeated platform usage develops into a behavioural routine that bypasses explicit cognitive evaluation (Liu et al., 2023; Sharma et al., 2024). For platforms, this means that even before service-quality perception fully consolidates, sustained engagement can begin to build the habits that anchor retention.

Theoretical and Practical Implications

Theoretical implications

Four theoretical implications follow.

Disaggregation matters. Treating user engagement as an aggregated construct masks substantial heterogeneity in how engagement reaches retention. The four-strand decomposition advanced here - task cognition, information seeking, effort expenditure, human-computer interaction - is empirically defensible (distinct factor structure, distinct path weights, distinct moderation patterns) and theoretically meaningful (each strand corresponds to a different cognitive-behavioural resource). Future research in digital-platform settings should resist the temptation to lump.

Perceived service quality is a mechanism, not an end-point. The traditional SERVQUAL apparatus has tended to position service quality either as an antecedent of satisfaction or as an outcome of design choices. The mediation result here, in concert with prior work in adjacent settings (Monoarfa et al., 2024), suggests instead that perceived service quality is the cognitive bridge between user-side stimulus and behavioural response, with implications for how the construct is theorised and measured going forward.

Participatory stimuli enrich the S-O-R framework. The S-O-R framework has been applied widely in digital commerce but most often with platform-side stimuli (interface design, information quality, environmental cues). Treating user engagement as a stimulus - a co-productive stimulus that the user supplies through their own activity - is consistent with service-dominant logic and aligns S-O-R with the participatory turn in contemporary marketing theory (Cheng et al., 2024; Gao et al., 2015).

Technology-related apprehension is path-conditional. The result that apprehension moderates only the cognitively demanding route invites theoretical refinement. The technostress literature increasingly distinguishes between techno-eustress and techno-distress and emphasises that distress is task-specific rather than person-specific (Tarafdar et al., 2019). The present finding extends that argument into a domain-specific empirical context and provides a falsifiable mechanism (cognitive-load competition) for why path-conditional moderation should occur.

Practical implications for platform operators

For fresh-grocery platform operators, the results are consistent with effort engineering, complementing, rather than simply minimising, the work asked of the user, as a design orientation. Because effort expenditure carries the largest path to service-quality perception ($\beta = 0.239$) and a significant direct path to continuance intention, designing the platform so that each tap surfaces relevant information, each filter usefully narrows the option set, and each interaction yields a tangible benefit is likely to convert user effort into perceived quality. Given the modest effect sizes, however, these implications are offered as directional guidance rather than firm prescriptions.

A second implication concerns the management of perceived service quality. Operators tend to monitor objective performance metrics - fulfilment time, return rates, app crash counts - but the data here suggest they should equally invest in perception-measurement infrastructure: brief in-app surveys after delivery, sentiment analysis of review text, response-quality scoring for chat interactions. Perceived service quality is the variable that converts performance into retention, and it cannot be measured purely through backstage metrics.

A third implication concerns segmentation. Apprehensive users do not need a different platform but they do need a different informational interface: simpler search, more visual product representation, guided checkout flows, clear and unambiguous promotion explanations, decision-support

tools that pre-process comparison information. The current results suggest that these interventions will have measurable returns precisely on the informational-acquisition route (which is where apprehension's moderation bites) and will likely yield smaller returns when targeted at effort-side or interaction-side bottlenecks.

Practical implications for merchants and supply-side operators

For merchants and supply-side operators, the model implies that product-information quality and fulfilment reliability are not merely operational metrics but inputs into the user's perception-formation process. Provenance disclosure, accurate product descriptions, traceable freshness indicators, transparent pricing, and post-purchase responsiveness all feed into the perceived service quality that mediates retention. Investments in supply-side coordination - cold-chain reliability, last-mile efficiency, return-handling responsiveness - are most likely to translate into retention when they are made visible to the user through information presentation.

Practical implications for policymakers and the industry ecosystem

Because the estimated effects are modest, the following are offered as directions for governance rather than firm prescriptions. For policymakers, the model suggests that regulatory attention could expand beyond transaction security toward an integrated framework addressing platform accountability, service-quality standards, consumer experience, and digital inclusion: **1)** industry-level service-quality standards for fresh-grocery platforms (product quality, fulfilment reliability, after-sales remediation, information transparency, interface usability) could help shift competition from price-based to service-based dynamics; **2)** consumer-information governance could require not only formal disclosure but substantive comprehensibility, given the documented role of information seeking and the moderating role of apprehension on that route; **3)** digital-inclusion measures (interface design for older users, accessible payment, low-friction onboarding) could help address the apprehension-related inequality the model points to; and **4)** cross-stakeholder governance could help institutionalise the experience-monitoring infrastructure the model implies.

For the wider industry ecosystem, the model offers a pivot from traffic-driven competition toward relationship-driven operation, in line with growing evidence that sustainable growth in digital retail depends increasingly on user repurchase, relationship quality, service stability, and ecosystem synergy rather than on traffic acquisition alone.

Limitations and Future Research

The study has limitations that bear on interpretation and on the design of subsequent investigations.

Cross-sectional design. Because all variables were measured at a single point in time, causal sequencing - even with a tightly specified S-O-R structural model - is supported by theory rather than confirmed by design. Longitudinal or panel-data designs could track the same cohort of users across multiple platform interactions and identify how engagement strands accumulate into perception and habit over time.

Self-reported instrumentation. All constructs were measured via respondent self-report. Despite Harman's test, anonymity assurances, and reverse-coded items, residual common-method variance cannot be ruled out completely. Triangulating survey responses with platform-side behavioural data (click paths, time-on-page, transaction logs, review histories) would strengthen inference by combining subjective perception with objective behavioural signal.

Self-reported instrumentation and common-method variance. All constructs were measured via respondent self-report from the same individuals at a single time point. Despite Harman's single-factor test, the full-collinearity assessment (all VIFs < 3.3), anonymity assurances, and reverse-coded items, residual common-method variance cannot be fully excluded. Triangulating survey responses with platform-side behavioural data (click paths, time-on-page, transaction logs, review histories), or separating the measurement of predictors and outcome across occasions or sources, would strengthen inference.

Mono-method analytical strategy. PLS-SEM is well suited to the structural complexity of the model but does not produce the global-fit machinery of covariance-based SEM. Cross-validation against CB-SEM, hierarchical regression, or Bayesian SEM would help adjudicate whether the substantive results are method-sensitive. Sensitivity analyses across sample subsets and alternative model specifications would similarly help assess robustness.

Linearity assumption. The structural model is linear-in-parameters. Real consumer responses may exhibit threshold effects, diminishing marginal returns, or asymmetric reactions to losses and gains. Nonlinear regression, quantile regression, or fuzzy-set qualitative comparative analysis (fsQCA) could surface configurational patterns invisible to a purely linear model ([Pu et al., 2025](#)).

Geographic and platform-segment scope. The empirical setting is one province (Guangdong) and one segment (fresh-grocery), albeit a province and segment chosen for their representativeness and dynamism. Cross-provincial and cross-segment replication would help establish where the model's parameter estimates remain stable and where regional, infrastructural, or category-specific moderators come into play.

Geographic, platform-segment, and sampling scope. The empirical setting is one province (Guangdong) and one segment (fresh-grocery). Equally important, the sample was recruited through purposive and convenience-based online channels and is therefore non-probabilistic; the parameter estimates should be generalised with caution and re-exam-

ined on probability-based and cross-provincial samples before broad claims of representativeness are made.

Construct scope. The model intentionally focused on a four-strand engagement decomposition, a single mediator, and a single moderator. Other plausible drivers of continuance intention - price sensitivity, brand trust, perceived value, social influence, platform stickiness, habit - were excluded for analytical clarity. Future work could extend the model to integrate digital-psychology variables (technology self-efficacy, digital trust, perceived privacy risk, technology fatigue) and platform-ethics variables (algorithmic transparency, recommender-system fairness, data-governance perceptions) (Tarafdar et al., 2019).

Mixed-methods complement. The structural model identifies patterns but not the textured, situational micro-experience that produces them. Pairing the structural-model evidence with qualitative interviews, focus groups, or user-experience tracking would deepen interpretation, especially around the asymmetric moderation result and the apparent dominance of effort expenditure.

Continuance-intention measurement. The continuance-intention construct bundles continued use, preference, recommendation, and primary-channel intentions. Although these items are empirically unidimensional in this sample, the recommendation (word-of-mouth) facet is conceptually distinct from repurchase, and future research could model advocacy as a separate behavioural outcome.

Conclusion

This study has examined how the user-side architecture of platform engagement translates into continued use of fresh-grocery e-commerce, taking the Guangdong market as its empirical setting. The four-strand decomposition of engagement - task cognition, information seeking, effort expenditure, and human-computer interaction - is documented here as an expanded account of the same core model and dataset reported by Yue et al. (2026). Each strand raises the user's perception of service quality; effort expenditure shows the largest effect; perceived service quality in turn translates into continuance intention; and technology-related apprehension acted, in this sample, as a path-conditional rather than a uniformly generalised inhibitor, weighing principally on the cognitively demanding information-acquisition route. These results contribute to ongoing theoretical conversations about the architecture of customer participation, the mediating role of perceived quality, the participatory reframing of stimulus-organism-response logic, and the path-specificity of technostress; they also provide cautious, design-oriented guidance for platform operators, merchants, and policymakers attempting to convert engagement into durable retention in a maturing and increasingly contested digital-retail segment. These conclusions should be read in light of the study's cross-sectional, single-region, non-probability design and the modest magnitude of the estimated effects.

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Appendix A. Measurement Instrument

All items were rated on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree) and were adapted from the sources listed in Table 1 and contextualised to the fresh-grocery platform setting. Reverse-coded items, marked (R), were recoded before analysis.

Table A1 | Full measurement instrument by construct

Construct	Code	Item wording
Task cognition (IV01)	WC1	I understand how this fresh-grocery platform's ordering and delivery process works.
	WC2	I am familiar with the navigation and category structure of the platform.
	WC3	I know how the platform's promotion and discount rules are applied.
	WC4	I understand the steps required to turn browsing into a confirmed delivery order.
	WC5	I can correctly interpret the platform's delivery time-slot and fulfilment information.
Information seeking (IV02)	IS1	Before buying, I actively read product provenance and freshness information on the platform.
	IS2	I compare supplier ratings and user reviews before selecting fresh products.
	IS3 (R)	I rarely check delivery-window or logistics information before placing an order.
	IS4	I look up promotion details and price comparisons within the app before purchasing.
	IS5	When needed, I seek additional product information from sources outside the platform.
Effort expenditure (IV03)	EF1	I am willing to spend time selecting the most suitable delivery time-slot.
	EF2	I make the effort to write custom notes or special requests for my fresh-grocery orders.
	EF3	I am willing to adjust my schedule to receive fresh deliveries on time.
	EF4	I actively participate in the platform's review or feedback programmes.
	EF5	I tolerate minor product imperfections and follow up rather than abandoning the platform.
Human-computer interaction (IV04)	HCI1	The platform's filtering and category tools respond smoothly to my actions.
	HCI2	The intelligent search returns results that match what I am looking for.
	HCI3 (R)	I often find the in-app customer-service interaction unresponsive or confusing.
	HCI4	Moving from browsing to cart to checkout feels seamless on the platform.
	HCI5	The platform interface makes it easy for me to complete my fresh-grocery tasks.
Service-quality perception (MED)	SQ1	The packaging and delivery presentation of my fresh orders are of high quality.
	SQ2	Products arrive fresh and on time as promised.
	SQ3	The platform responds quickly and effectively to after-sales problems.
	SQ4	I trust the provenance disclosure and payment security of the platform.
	SQ5	The platform offers regionally tailored options and flexible delivery windows that suit me.
Continuance intention (DV)	CI1	I intend to keep purchasing fresh groceries from this platform.
	CI2	I will continue to use this platform rather than switch to alternatives.
	CI3	I prefer this platform over other fresh-grocery options.
	CI4	I would recommend this platform to others.
	CI5	I regard this platform as my primary channel for buying fresh groceries.
Technology-related apprehension (MODV)	TA1	I feel uneasy when using new features on the fresh-grocery platform.
	TA2	I worry about making mistakes when operating the platform's technology.
	TA3	Interacting with the platform's digital tools makes me nervous.
	TA4 (R)	I feel confident and at ease when trying the platform's new technological features.
	TA5	I am concerned about data privacy and security when using the platform.

Note. (R) = reverse-coded item (recoded before analysis). Five-point Likert response (1 = strongly disagree, 5 = strongly agree). Items adapted from the sources in Table 1 and contextualised to the fresh-grocery setting (e.g., “delivery time-slot”, “freshness inspection”).

Research on the Digital Interpretation and Design of Lingnan Xiangyunsha Intangible Cultural Heritage Technique Empowered by AIGC

Chen Chen ^{1,*}, Yongle Zeng ¹, Jiapeng Li ¹

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Abstract: Based on the theory of image narrative, this study focuses on the three value dimensions of the national intangible cultural heritage project, the Xiangyunsha dyeing and finishing technique: ecological foundation, artistic features, and cultural circulation. It constructs a triple semantic narrative axis of "natural symbiosis - craftsmanship - maritime trade" and explores the multimodal digital display design process in a virtual reality (VR) environment. By using AIGC-assisted image generation, 3D modeling, and immersive interaction design, a digital display system for ecological narrative space, craftsmanship narrative content, and trade narrative scenarios is constructed. This dynamic image narrative in a virtual reality environment not only effectively restores the complete process and cultural context of the Xiangyunsha intangible cultural heritage technique but also enhances users' immersive experience and emotional connection to the intangible cultural heritage value, improving the cross-temporal and spatial dissemination power and public recognition of the intangible cultural heritage value. The "image narrative + AIGC generation + VR immersion" digital display design proposed in this study provides an operational and extensible design framework for the digital revitalization of intangible cultural heritage and has theoretical and practical significance for promoting the innovative dissemination and cultural value reconstruction of intangible cultural heritage.

Keywords: Xiangyunsha; Intangible cultural heritage; Image narrative; Virtual reality; Digital display design

Introduction

Under the backdrop of the vigorous promotion of the "Digital China" strategy by the state, the digital protection, dissemination and innovative expression of intangible cultural heritage are experiencing unprecedented development opportunities. The "Overall Layout Plan for Digital China Construction" released in 2023 explicitly states that it is necessary to "accelerate the digital layout of the cultural industry and innovate cultural expression methods", emphasizing the empowerment of cultural inheritance through digital technology and the creative transformation and innovative development of intangible cultural heritage projects. Meanwhile, relevant departments such as the Ministry of Culture and Tourism have successively issued policy documents such as

the "14th Five-Year Plan for Cultural and Tourism Development" and the "Notice on Promoting the Digitalization of Intangible Cultural Heritage", providing policy support and direction for the digital revitalization of intangible cultural heritage.

As a representative national-level intangible cultural heritage project in the Lingnan region, the "three washes, nine boils and eighteen sunnings" dyeing and finishing technique of Xiangyunsha has a long production cycle and complex procedures, facing difficulties such as being difficult for the public to understand and insufficient inheritance capacity. In recent years, the academic community has conducted multi-dimensional discussions on the intangible cultural heritage (ICH) inheritance and digital protection of Xiangyunsha. Wen Xia and others have conducted sys-

¹ School of Art & Design Guangdong University of Technology, Guangzhou 510090, China.

* Corresponding author. Email: chenchen@gdut.edu.cn.



Figure 1 | The "GuoWU" process of Xiangyunsha



Figure 2 | Scene of Xiangyunsha fabric being dried in the sun

tematic research on the digital protection of Xiangyunsha dyeing and finishing techniques. Through field investigations and sample tests, they have established a relatively complete data foundation and visualized process flow, providing a model support for the systematic recording of complex process flows[1]. Bao Lei, from the perspective of sustainable development, emphasizes that Xiangyunsha, as an ICH fabric with an environmental protection concept, its design innovation not only helps cultural inheritance but also promotes its entry into the international fashion context[2].

However, current research still generally focuses on the establishment of digital archives and the analysis of cultural values. Studies on the specific application of image narration in the dissemination of intangible cultural heritage are relatively weak, and there is insufficient exploration of multi-modal narration and interaction mechanisms in virtual reality environments. Especially in the dynamic reproduction of the complexity of the Xiangyunsha dyeing and finishing process and the construction of narrative structures, there is a lack of systematic and operational display models. Therefore, this study focuses on the ecological basis, artistic features and cultural circulation value elements of the Xiangyunsha dyeing and finishing technique, and constructs a narrative axis of "natural symbiosis - craftsmanship - maritime silk trade". Then, it uses AIGC to assist in image generation and reproduces the narrative semantics through 3D modeling, and builds an immersive digital display system with the help of virtual reality technology. Through the public experience evaluation of its usability, it realizes the emotional connection between the public and the value of intangible cultural heritage. Thus, it breaks the geographical restrictions to achieve cloud sharing, expands the coverage of the dissemination of Xiangyunsha intangible cultural heritage techniques, and aims to comprehensively demonstrate the narrative attributes of the living inheritance of intangible cultural heritage and provide a demonstrative solution for digital display design.

The Inheritance and Digital Exhibition of The Intangible Cultural Heritage Value of Xiangyunsha

Value elements of intangible cultural heritage skills

As a distinctive intangible cultural heritage of the textile category in the Lingnan region, Xiangyunsha showcases the integrated heritage value of its ecological foundation, fabric artistry, and cultural circulation through the dyeing and finishing technique of "three washes, nine boils, and eighteen sunnings". This dyeing and finishing technique adheres to the traditional Chinese philosophy of "harmony between man and nature", and is produced in the "mulberry pond and fish pond" ecological environment where the people of Lingnan coexist in harmony with nature. The entire production process is highly dependent on natural resources and climatic conditions, demonstrating the artisans' profound understanding of the synergy between time rhythms, environmental changes, and artificial manufacturing. The core "blackening" process (Figure 1) uses specific river mud and the juice of the Ipomoea batatas plant to create a natural oxidation reaction, giving the fabric a unique two-sided color and lustrous texture after multiple sunnings, forming an eco-friendly natural dyeing and finishing system. The sunning process follows the natural solar terms and time rhythms, reflecting the traditional artisans' precise perception and adaptation to environmental factors such as sunlight intensity and wind direction (Figure 2). This not only avoids the ecological damage caused by chemical dyes but also endows Xiangyunsha with the cultural connotation of "acting in accordance with the times and going with the flow".

The Xiangyunsha fabric presents a visual style rich in the aesthetic qualities of the East. Its color is low-key and steady. The common brown and black tones on the silk surface emit a soft luster, forming an understated and reserved aesthetic



Figure 3 | The "simple and elegant beauty" of Xiangyunsha

connotation, conveying the pursuit of "simple and elegant beauty" [3] (Figure 3). This color language stems from the admiration of the beauty of natural materials and is distinct from the bright and intense color tones of modern industrial dyeing and finishing. It not only retains the practicality of the fabric but also demonstrates fluidity and a sense of ceremony in its structural cutting and wearing experience, still possessing a strong artistic appeal in the contemporary design context.

As an important commodity on the Maritime Silk Road, the production technology of Xiangyunsha has been constantly updated and passed down throughout history. From being a tribute to the imperial court in the Qing Dynasty to an export specialty in the Guangzhou-Foshan region in modern times, the production of Xiangyunsha not only shaped a regional handicraft ecosystem but also witnessed the commercial exchanges and cultural intercommunication in the Lingnan region. During its cross-regional dissemination, Xiangyunsha was not only sold far to Southeast Asia, Europe and America, but also adapted to the aesthetic and functional demands of different markets[4]. For instance, to cater to the humid climate and the clothing preferences of the Chinese community in Southeast Asia, local innovations were made in the fabric patterns and color treatments; while for the European and American markets, more emphasis was placed on its eco-friendly and natural dyeing concepts, in line with the international consumers' concern for sustainable fashion. This cultural circulation mechanism of local production, global circulation and aesthetic adaptation makes Xiangyunsha both local and international, constituting a typical model of cultural hybrid craftsmanship.

Since being included in the National List of Intangible Cultural Heritage Representative Items in 2008, the Xiangyunsha dyeing and finishing technique has received institutional protection and the promotion of diverse dissemination, becoming an important symbol of Lingnan cultural identity. With the empowerment of digital and virtual reality

technologies, it has presented new paths of dissemination and possibilities for dynamic inheritance.

The image narrative attributes of intangible cultural heritage skills

In recent years, image narrative has gradually become a hot topic in the research of digital and cultural communication as an important path for the digital revitalization of intangible cultural heritage (ICH). Current research mainly focuses on three aspects: First, by leveraging technologies such as virtual reality (VR) and augmented reality (AR), multi-modal narrative systems integrating images, sounds, interactions, and texts are constructed to enhance immersive experiences and user engagement, transforming ICH from "static display" to "experiential communication". Second, attention is paid to the recording and dissemination effects of digital images of ICH, analyzing the influence of image elements such as frame rate, change frequency, and gradient rhythm on audience perception and cultural understanding. Third, from the perspective of cultural memory construction and emotional connection, it explores how image narrative can strengthen the cultural expression and sense of identity of ICH, and enhance the depth of ICH dissemination and public participation through interactive digital media. These studies collectively indicate that image narrative is not only a medium for the visual expression of ICH but also an important driving force for the semantic extension and dynamic inheritance of its culture.

Despite this, current ICH image narratives still face many challenges in practical application, especially in the systematic recording and visual representation of skill processes. ICH skills are mostly passed down through oral instruction and demonstration between masters and apprentices, lacking systematic digital archiving and process tracking mechanisms.



Figure 4 | Synergistic space of nature and agricultural activities in Mulberry-fish pond systems

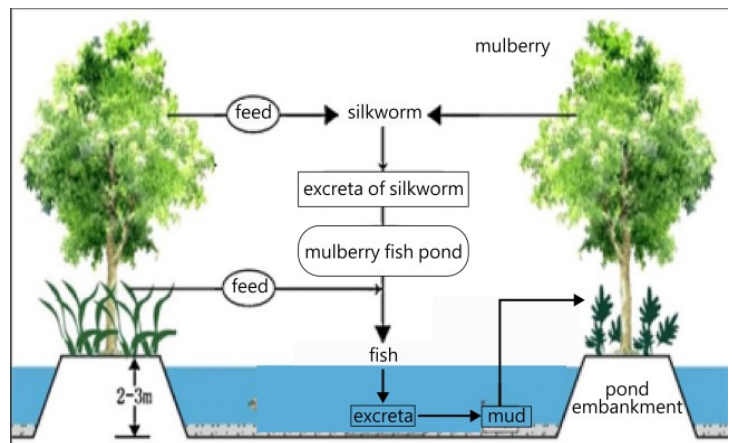


Figure 5 | Ecological closed loop of mulberry fish ponds

As a result, image materials often remain as fragmented static records, making it difficult to support a complete and coherent narrative construction. For instance, the dyeing and finishing process of Xiangyunsha fabric is highly complex and dependent on natural conditions. Its key steps, such as the "blackening" process, involve the natural reaction of plant dyes and specific soils, which are difficult to standardize and reproduce in image modeling and visual expression, thereby affecting the visual interpretation of its deep cultural connotations.

Digital presentation methods of intangible cultural heritage images

In the contemporary context where the digital dissemination of intangible cultural heritage is continuously deepening, the display of intangible cultural heritage presents diversified paths combining offline museums, craft workshops, and online museum APPs. This breaks through the closed nature and participation threshold of previous localized display spaces and expands the breadth and depth of intangible cultural heritage dissemination. Existing research mostly focuses on technical implementation paths such as 3D modeling, virtual display, and interactive experience, promoting the visual preservation and online dissemination of intangible cultural heritage information[5]. Some scholars have attempted experimental research from directions such as immersive narrative and digital person interpretation[6], but there are still deficiencies in cultural semantic refinement, visual narrative design, and the mechanism of audience emotional resonance.

The current mainstream online platforms for intangible cultural heritage display still mainly present single-directional museum models and craft introductions, lacking cross-temporal, all-process, and multi-dimensional image narrative support, making it difficult to fully mobilize the sensory and emotional participation of the audience. Taking Xiangyunsha as an example, this type of intangible cultural heritage has a relatively monochromatic color, a complex techni-

cal process, and lacks systematic image records, and its audience is highly regional. Due to these characteristics, there are technical bottlenecks in technical restoration, making it difficult to effectively attract young audiences in the digital context. This situation further restricts the visual depth of digital reconstruction and the operational space for cross-media dissemination of this type of intangible cultural heritage, and urgently requires the construction of an innovative image narrative mechanism that integrates semantic understanding and emotional connection.

The Narrative Axis of Xiangyunsha Intangible Cultural Heritage Skills

The narrative space of natural symbiosis

The dyeing and finishing process of Xiangyunsha is not only a highly complex manual procedure but is also deeply rooted in the unique ecological environment and agricultural system of the Lingnan region, especially the traditional agricultural ecological model of "mulberry pond fish farming" (Figure 4), which provides a stable material foundation and philosophical support for the production of Xiangyunsha[7]. This system forms a self-sufficient and circular ecological space through the coordinated cycle among mulberry tree planting, silkworm breeding, silk weaving, and fish pond farming, embodying the ecological consciousness of "harmony between man and nature" in the Lingnan region at the practical level.

In this system, the fertile alluvial plain is transformed into a good foundation for planting and breeding by building ponds with water diversion. Mulberry trees are planted on the pond banks, and the leaves are used for silkworm breeding. After the silkworms are harvested, the cocoons can be reeled to produce raw silk for Xiangyunsha production. Meanwhile, the silkworm droppings and mulberry leaf residues are returned to the soil, serving as natural fertilizers for the crops around the ponds, further enhancing soil



Figure 6 | Space for the weaving of Xiāngyúnsha

fertility. At the same time, the fish in the ponds purify the water during feeding, and their excrement and organic matter at the bottom of the ponds can also be used as fertilizers to nourish the mulberry fields, achieving an ecological closed loop of "fish nourishing mulberry, mulberry nourishing silkworm, silkworm producing silk, and silk weaving into cloth" (Figure 5). This forms a complex spatial image of mulberry fields, fish ponds, mulberry trees, and silkworms, reflecting the spatial logic and temporal rhythm of human and nature collaboration. Mulberry pond fish farming is not only an agricultural technology system but also an ecological wisdom that harmonizes production with nature, constituting the natural symbiotic narrative space for the generation of Xiāngyúnsha and conveying the narrative logic of natural changes, agricultural activities, and artificial weaving (Figure 6). It is an image-based representation of the cultural context of Xiāngyúnsha intangible cultural heritage "growing from the land" [8].

Narrative content of craftsmanship

The intangible cultural heritage of Xiāngyúnsha is renowned for its natural dyes and manual processes, whose complexity and rhythm form a highly expressive content section in the narrative of intangible cultural heritage images. This craftsmanship not only embodies the traditional textile wisdom of the Lingnan region but also constitutes the core narrative content of "craftsmanship".

The entire process begins with the "four water washes" of the tuberose (Figure 7). The craftsman needs to wash the tuberose four times to remove impurities and activate the dyeing activity, thereby forming a stable and usable dye solution. This dye solution is then used for the first immersion dyeing of the natural silk fabric, laying the color foundation for the entire process. After the first water wash following the immersion dyeing, the dye is evenly penetrated through water washing. Subsequently, the "sprinkling of tuberose water" (using the solution from the second water wash of the tuberose) and "color sweeping" processes are carried out,

where a brush is used to evenly apply the dye solution to enhance the color consistency of the fabric. This series of processes needs to be repeated six times, with each round of sprinkling and sweeping followed by drying and "sealing with tuberose" (using the solution from the third water wash of the tuberose), forming a stable dye layer and enhancing the luster of the fabric. This combination of drying and sealing with tuberose also needs to be repeated six times. The subsequent "boiling of silk" process enhances the flexibility of the fabric and the fastness of the dye through high-temperature boiling. Then comes the "second sealing with tuberose", where the fabric is continuously sealed and dyed with the solution from the fourth water wash of the tuberose, and this process is repeated twelve times in combination with drying operations, gradually deepening the color layers and texture structure. This stage is a critical point for the construction of color and texture and is also an important manifestation of the craftsman's experience and control over the process. In the final finishing stage, the fabric needs to be boiled again to stabilize the fiber state, and the "blackening", "washing black", "third sealing with tuberose", and "sprinkling mist" processes are completed in sequence. In the blackening process, the fabric undergoes a natural reaction with iron-rich river mud, generating a unique black-brown color effect; the third sealing with tuberose still uses the solution from the fourth water wash to further consolidate the color and luster. Finally, through "sprinkling mist", the fineness and hand feel of the fabric are enhanced to produce the typical characteristics of Xiāngyúnsha [9].

The dyeing and finishing process of Xiāngyúnsha creates diverse images through the combination of tools, materials, manual techniques, and natural environments. It showcases the rhythm and stages of the process through unique workflow nodes, and forms dynamic interactions between micro-operation details and natural environmental conditions, demonstrating the deep understanding and aesthetic tendencies of traditional craftsmanship in collaborative creation with natural resources.

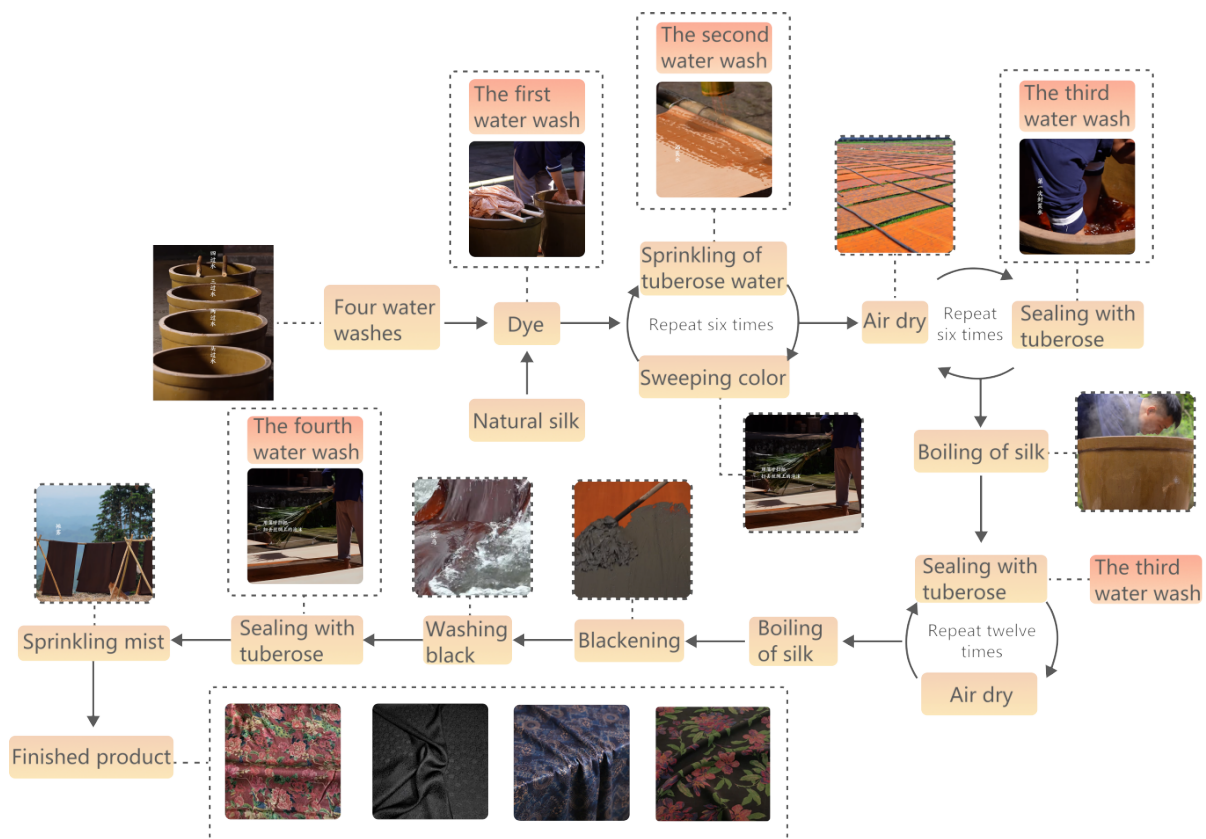


Figure 7 | Dyeing and finishing process technology procedures of Xiāngyúnsha

The narrative context of maritime silk road trade

The dyeing and finishing techniques, which integrate natural wisdom and ingenious craftsmanship, have created the Xiangyunsha handicrafts with a distinct Lingnan style. These products were circulated overseas along with the prosperity of the Maritime Silk Road[10]. As a specialty export product of the Guangzhou-Foshan region in the modern foreign trade system, Xiangyunsha gradually entered the international market through trade hubs such as the Thirteen Factories in Guangzhou since the Qing Dynasty, and was sold to Southeast Asia, the Indian Ocean coast, and some countries in Europe and America. Its unique fabric style, which is understated yet rich in texture, meets the aesthetic expectations of specific cultural consumer groups for oriental handicrafts, making it an important medium for the exchange of clothing and cultural imagination between China and the West.

Driven by trade flows, not only were large quantities of Xiangyunsha products exported through maritime networks, but the dyeing and finishing techniques behind them were also gradually recognized and absorbed by foreign regions. On the one hand, the craft workshops in the Guangzhou-Foshan area gradually formed a large-scale and specialized division of labor system, completing the production and export process of Xiangyunsha through the organizational struc-

ture of guilds, workshops, and ports. On the other hand, these technological knowledges influenced the surrounding regions through cultural exchanges, giving rise to the evolution and integration of dyeing and finishing techniques for Nanyang native cloth, demonstrating the cultural export capacity of traditional techniques as soft technologies. The cultural flow formed a narrative context where material representation and cultural expression are integrated, reflecting that Xiangyunsha is not only a representative of Lingnan regional culture but also a key node connecting local handicrafts with the global cultural market. Its early practice in the global dissemination of intangible cultural heritage provides historical references and cultural depth for today's digital display and international exchanges.

The ecological foundation of the Xiangyunsha dyeing and finishing techniques, the craftsmanship process that gives rise to artistic features, and the cultural circulation brought by the Maritime Silk Road trade have formed a narrative axis from narrative space to context integration of "natural symbiosis - craftsmanship - Maritime Silk Road trade"(Figure 8), comprehensively embodying the ecological, technical, and cultural values of Xiangyunsha dyeing and finishing techniques.

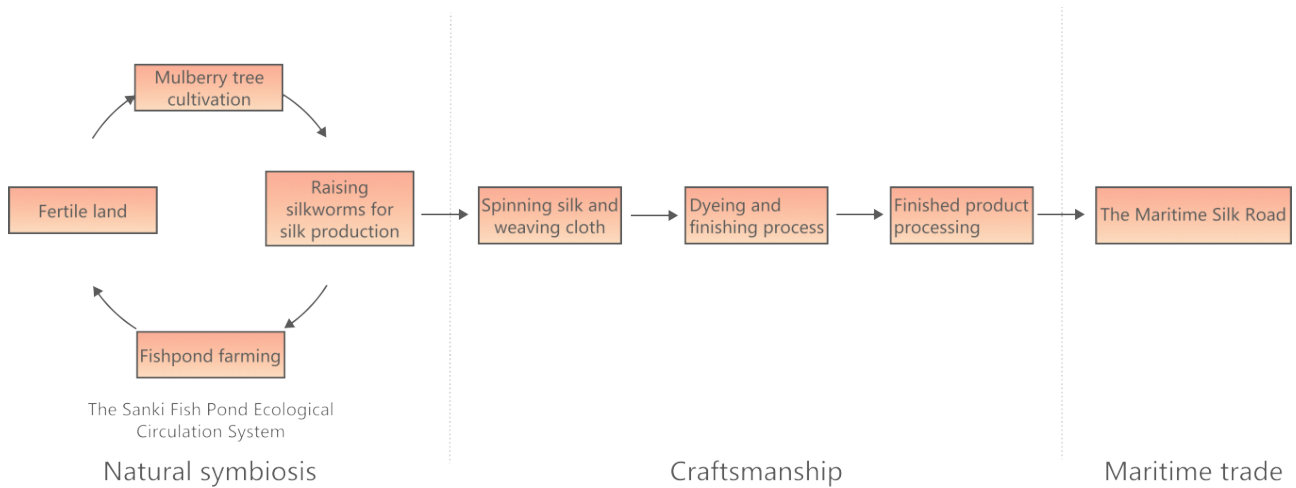


Figure 8 | "Natural Symbiosis - Artisanal Craftsmanship - Transoceanic Trade" narrative axis

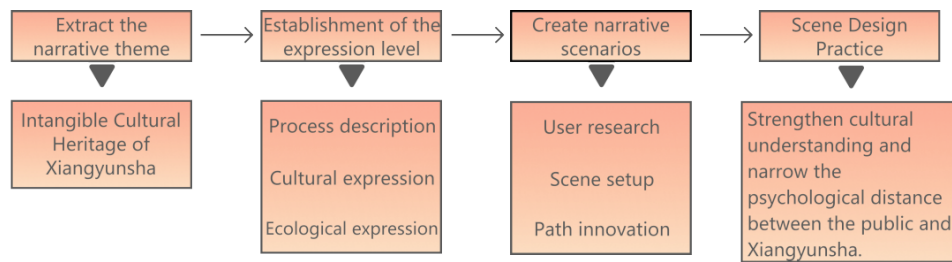


Figure 9 | Digital design process diagram of Xiangyunsha intangible cultural heritage

VR Presentation and Interactive Experience Design of Xiangyunsha Dyeing and Finishing Techniques

This research employs AIGC for the image translation of narrative axes, and through the sequential and scene-based expression of images, establishes a four-level digital display design process for Xiangyunsha dyeing and finishing techniques: the refinement of narrative themes, the establishment of expression levels, the creation of narrative scenes, and the specific practice of scene design (Figure 9). This aims to achieve an immersive, structured, and multimodal digital communication effect, enhancing users' perception and understanding of the intrinsic semantics of intangible cultural heritage, and promoting the transformation of immersive narrative experiences from viewing to understanding, and from formal reproduction to cultural transmission.

The digital display focuses on the "image narrative characteristics of Xiangyunsha dyeing and finishing techniques", emphasizing the integration of educational and aesthetic values in value dissemination, and clarifying the dual goals of reaching the general public and cultural inheritance. Immersive scene construction is carried out from three dimensions: ecology, craftsmanship, and culture. The ecological

narrative space image of the mulberry pond and fish pond conveys the ecological awareness of the harmony between Xiangyunsha and nature; the visualization of the dyeing and finishing process images realizes the complete reproduction of the craftsmanship; and the exploration of the maritime silk trade scene reveals the systematic relationship between the evolution of the craftsmanship and cultural flow. Based on AI image generation and virtual reality (VR) technology, a digital display system is designed and constructed, integrating the visual language style transfer of the Lingnan School of Painting, dynamic interpretation of the craftsmanship process, immersive exhibition environment, and interactive interface design. Further, through user experience and usage requirements, the usability of this design is verified to achieve an emotional connection between the public and intangible cultural heritage. This display design path that integrates the value of intangible cultural heritage with digital technology forms a dyeing and finishing techniques display process from value exploration to interactive experience through image narration, which can enhance the public's overall cognition and perceptual participation in Xiangyunsha intangible cultural heritage.

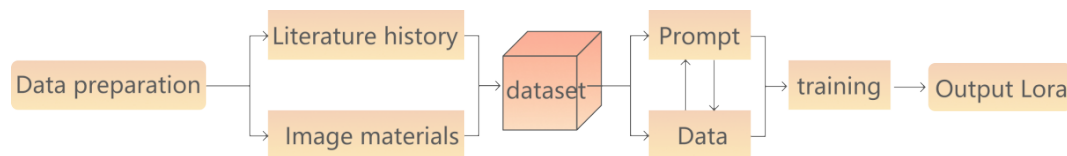


Figure 10 | Flowchart of LoRa model training

AIGC process visualization image generation

The narrative space, content, and context of the Xiangyunsha dyeing and finishing technique are presented through AIGC-generated images, forming an emotional connection between the viewer and the intangible cultural heritage content through visual information such as composition, color, rhythm, and symbols[11]. Through multi-level narrative perspectives, it guides the viewer's involvement and presents the information hierarchy and logic of the technique's value in the changes of narrative rhythm. It carries deep cultural semantics through space, manufacturing, and trade activities, forming a visually recognizable memory.

The design systematically collects and organizes the narrative space forms of the mulberry pond fishpond, the patterns and process images of Xiangyunsha, covering pattern data from historical documents, museum collection images, and local workshop records. By deconstructing the semantics of these visual materials, it identifies the process features and cultural symbols contained within: for example, the interaction between fabric and land and water flow in the sun-drying process reflects the symbiotic relationship between Xiangyunsha dyeing and finishing technique and the natural ecosystem; the deep black luster formed by repeatedly applying the tuberous morning glory liquid in the "blackening" process has strong oriental aesthetic connotations and ritualistic characteristics. This process builds a semantic coordinate system for the Xiangyunsha process images, providing a semantic annotation basis for AIGC stylized image generation. By sorting out the intuitiveness (concrete form of visual reproduction), symbolism (image translation of cultural traditions), and simultaneity (parallel arrangement of process images from different historical stages) of the images, it achieves an effective transition from image understanding to content generation, ensuring the accuracy and continuity of cultural semantics in the generated images during style transfer and image narration.

Image generation is based on LoRa model training. The selection of LoRa fine-tuning was based on the characteristics of Xiangyunsha intangible cultural heritage image generation. Compared with full-model training methods, LoRa requires fewer training resources and can achieve efficient model adaptation with a relatively small number of domain-specific samples. This advantage is particularly suitable for intangible cultural heritage scenarios, where specialized image datasets are limited but the preservation of cultural and visual characteristics is essential. Therefore, LoRa was adopted to improve training efficiency while maintaining

the semantic consistency and visual representation of Xiangyunsha cultural elements. In the data preparation stage, historical images related to Xiangyunsha, traditional process photos, and typical works of the Lingnan School of Painting are systematically organized and collected to ensure that the materials have high resolution, accurate cultural annotations, and consistent style. The collected visual resources mainly include Xiangyunsha dyeing and finishing process images, traditional craftsmanship records, cultural pattern references, and ecological environment images related to the mulberry-dyke-fishpond system. These materials are integrated from historical documents, museum collection images, and local workshop records, forming a multi-source visual dataset that supports LoRa model fine-tuning and the learning of Xiangyunsha-related cultural semantics. Based on the characteristics of intangible cultural heritage image generation, the dataset focuses on preserving the process characteristics, cultural symbols, and visual styles of Xiangyunsha, providing a reliable visual foundation for subsequent semantic annotation and model training. (Figure 10) In the data set construction and label setting stage, the original images are classified and structured into multi-dimensional structured data sets, and specific semantic labels (such as "silkworm", "spraying the tuberous morning glory water", "dyeing", "traditional process scene", etc.) are set to provide clear semantic guidance for model learning. The semantic labeling strategy is established based on the key process characteristics, environmental contexts, and visual features of Xiangyunsha intangible cultural heritage. The labels are divided into three categories: process-related semantic labels, environmental context semantic labels, and cultural visual semantic labels. Process-related semantic labels describe specific dyeing and finishing procedures, such as dyeing, spraying the tuberous morning glory water, and sun-drying process, enabling the model to learn the characteristics of traditional craftsmanship. Environmental context semantic labels represent the ecological environment and spatial contexts associated with Xiangyunsha production, such as the mulberry-dyke-fishpond system and traditional workshop scenes. Cultural visual semantic labels focus on the artistic characteristics and symbolic elements of Xiangyunsha, including traditional patterns, natural dyeing colors, and Lingnan artistic styles. Through this hierarchical semantic annotation strategy, the relationship between visual features and cultural meanings is strengthened, helping maintain semantic coherence and cultural consistency in generated images. On this basis, prompt data for training is gener-

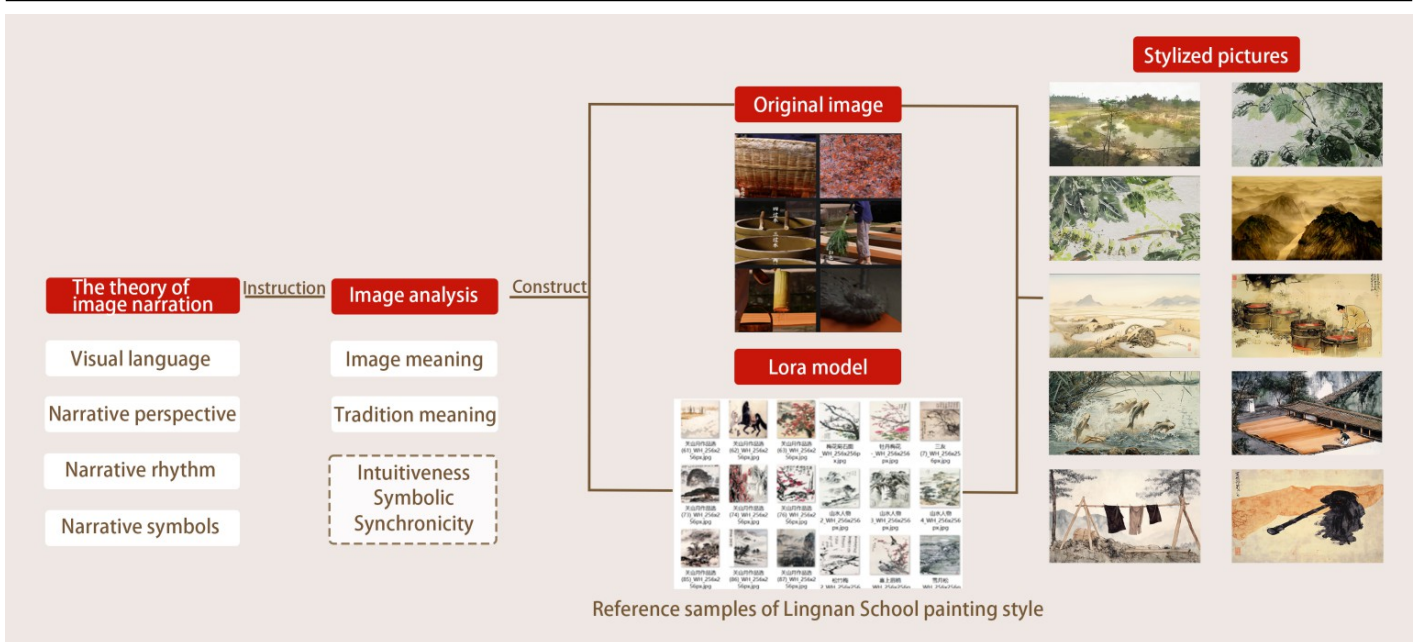


Figure 11 | Flowchart of AIGC process visualization image generation

ated, such as "traditional dyeing and finishing scene in the style of the Lingnan School of Painting", "the scene of a craftsman sun-drying", etc., to enhance the model's understanding of the target image's semantics and style. Then, in the model training stage, based on the Stable Diffusion model, the LoRA (Low-Rank Adaptation) fine-tuning method is adopted. By injecting low-rank matrices into the key layers of the model, efficient parameter updates and enhanced style transfer capabilities are achieved. During the training process, reasonable hyperparameters (such as a learning rate of $1e-4$, batch size of 2, and training rounds of 10-15) are set, and a combined text-image training strategy is used to improve the semantic and style consistency of image generation. Finally, in the model export and application deployment stage, the trained LoRA weight files are exported and integrated into the basic model system, supporting stylized image generation based on prompt control. (Figure 11) This process generates images with distinct characteristics of the Lingnan School of Painting, highly restoring the ecological basis and aesthetic features of the Xiangyunsha dyeing and finishing technique, and coordinating the integration of the Xiangyunsha process imagery, cultural expressiveness, and artistic appeal, forming a clear semantic and unified style visual narrative of intangible cultural heritage.

Interactive experience design for Xiangyunsha production

In the digital presentation of Xiangyunsha dyeing and finishing techniques, interactive experience design effectively enhances users' sense of immersion and can improve the understanding and dissemination efficiency of intangible cultural heritage knowledge. To build an immersive experience with cultural depth and technical compatibility, the de-

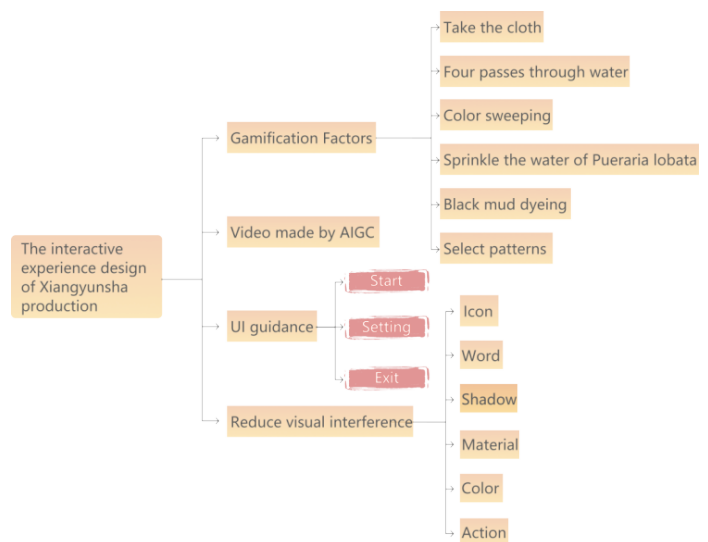


Figure 12 | Flowchart of AIGC process visualization image generation

sign explores from four dimensions: game mechanics, interaction logic design, natural interaction methods, and visual presentation, to construct an interaction system that aligns with the Xiangyunsha dyeing and finishing technique and user psychological models (Figure 12).

To break through the limitations of static browsing in traditional intangible cultural heritage (ICH) exhibitions, the system introduces a gamification mechanism. Through role-playing, task-driven and instant feedback methods, it enhances users' immersion and cultural participation[12]. Users will enter the virtual Xiangyunsha dyeing and finishing workshop as "apprentices" and complete the production



Figure 13 | Video clip of the "four water washes" process



Figure 14 | Video clip of the "sweeping color" process



Figure 15 | Video clip of the "sprinkling the latex water" process figure



Figure 16 | Video clip of the "blackening" process

processes of "taking the fabric - four water washes ([Figure 13](#)) - sweeping color ([Figure 14](#)) - sprinkling the latex water ([Figure 15](#)) - blackening ([Figure 16](#)) - selecting patterns" in sequence in the digital environment according to the real process. Each process is equipped with operation guidance and task challenge mechanisms, and users will receive dynamic scores and instant feedback based on the accuracy and completion of their operations, which encourages them to keep trying and learning. After completing all the process tasks, the system will unlock the virtual "Xiangyunsha Exhibition Hall" space, prompting users to view the virtual Xiangyunsha samples they "made by hand" and other historical patterns, process evolution, and cultural imagery displayed together, forming a complete experience chain from "hands-on practice" to "value perception". This interaction mechanism not only enhances users' active participation but also helps to deeply disseminate the knowledge of Xiangyunsha ICH and reconstruct cultural emotional connections.

The system is equipped with AIGC process videos to achieve an immersive experience of dynamic guidance and instant feedback. Before users carry out operations such as sweeping color, sprinkling latex, and drying, video clips will be automatically played in combination with the current interaction tasks and scene nodes, presenting the standard operation process and key process actions in real time, estab-

lishing a "see - learn - do" learning path, significantly enhancing the intuitiveness and cultural immersion of the interaction. The AIGC videos' strong semantic adaptation ability and flexible invocation mechanism will intelligently adjust the playback content based on the user's task progress, pause duration, or incorrect operation behavior[13]. At the same time, users can query process details, control playback progress, or repeat key steps through voice interaction commands, experiencing the content delivery of image narratives through both visual and auditory levels, enhancing the convenience and depth of personalized interaction.

To reduce the operational difficulty for users, the interaction process is modularized, breaking down complex process steps into clear operation nodes. This is complemented by visual illustrations, voice guidance, and animated demonstrations to form a multi-dimensional guidance system. The UI design adopts a minimalist style, creating a clearly partitioned interface layout and dynamic interaction prompts to ensure the immediacy and smoothness of information acquisition, avoiding excessive cognitive load and transforming the intangible cultural heritage process into an understandable and operable digital experience[14]. To enhance the user's immersion and cultural perception in the virtual environment, the system adheres to the "information minimization" principle in interface design, retaining only key prompts and necessary operation instructions, and mini-



Figure 17 | Restoration of the morphology of the Wok-ear house residential building



Figure 18 | Construction of the environment scene of the Xiangyunsha workshop

mizing interface distractions by reducing non-essential elements such as icons and text to prevent visual attention dispersion. During the interaction experience, users will be placed in the ecological space of Lingnan's mulberry pond fish ponds, always immersed in the first-person perspective of a craftsman, simulating their body movements and operation rhythms, and enhancing the "presence" and "participation" in the Xiangyunsha dyeing and finishing process. Through meticulous control of light, materials, and colors in the virtual space, the aesthetic tone of traditional Chinese craftsmanship is maintained, and the narrative coherence and visual concentration of the images are maximized, thereby more deeply conveying the cultural connotations and aesthetic features of the Xiangyunsha dyeing and finishing techniques[15].

Prototype development of the Xiangyunsha experience exhibition hall system

The design selects value elements such as architecture, rivers, and mulberry pond fish ponds from the ecological foundation of Xiangyunsha, and uses Maya for 3D modeling. It focuses on restoring the traditional residential form of the "Wok-ear House" (Figure 17) in Lingnan, as well as environmental elements in the Xiangyunsha workshop such as the drying ground, water tanks, and traditional drying racks, to construct a virtual display scene and create a narrative space atmosphere with regional characteristics (Figure 18).

Digital resources such as architectural models, natural scenes, production tools, terrain materials, typical patterns, and interactive operation interfaces are uniformly organized and imported into the Unity engine environment to achieve resource integration and system prototype development, providing a stable guarantee for subsequent interaction design and system deployment. The interaction system construction comprehensively uses the SteamVR Plugin and Playmaker plugin combination to develop virtual reality interaction logic. Among them, the SteamVR Plugin provides basic head-mounted display tracking and controller interaction support, ensuring that the system can be fully integrated with VR hardware devices; while Playmaker simpli-

fies the non-programming development process through the visual state machine (FSM) mechanism, making the construction of interaction logic more intuitive and efficient, suitable for multi-person collaboration and rapid iteration. The final system supports users to experience the dyeing and finishing process of Xiangyunsha in an immersive way, interactively select pattern samples, and view the status and evolution of Xiangyunsha in the maritime silk trade along the narrative axis of "natural symbiosis - craftsmanship - maritime silk trade", forming multiple interaction experiences from learning to exhibition(Figure 19-Figure 22).

Experiment

The digital display design of the Xiangyunsha dyeing and finishing techniques, which was established by the research through the combination of "image narrative + AIGC generation + VR immersion", needs to be evaluated for usability through user experience to verify the public's experience and feelings[16], so as to promote the improvement and optimization of the design. The usability experiment recruited 43 participants, covering different age groups from 18 to 65 years old, among which 40% were college students, 30% were enthusiasts of intangible cultural heritage, 20% were ordinary people, and 10% were inheritors of Xiangyunsha. This ensured the diversity and representativeness of the sample. All participants experienced the virtual reality scene constructed in this study through VR devices, which included three modules: "Sangji Fishpond Ecological Space", "Dyeing and Finishing Process Dynamic Interaction", and "Maritime Silk Road Trade Scenario Display". The experience duration was controlled within 30 minutes, and participants filled out the system usability scale after the experience.

The research designed the SUS scale with 10 standard questions, evaluating the user experience from dimensions such as "system ease of use", "learning curve", and "operation smoothness". For reverse-scored questions like "I found this system too complicated" and "I need technical support to operate this system", the original scores needed to be converted to positive scores. The total score after conversion



Figure 19 | Demonstration of the VR interaction system for Xiangyunsha



Figure 20 | Learning the making of Xiangyunsha



Figure 21 | "Guo Wu" interaction session



Figure 22 | Visiting the Xiangyunsha Virtual Exhibition Hall

for all questions was 35.08 points, and after multiplying by 2.5, the total SUS score of the system was 87.7 points. The specific questionnaire questions and score results are shown in [Figure 23](#). To further verify whether the system usability reached the industry benchmark level, this study used a one-sample T-test to compare the actual score with the theoretical benchmark value.

The experimental results showed that the system achieved positive performance in terms of usability and user-friendliness. Participants indicated a willingness to use the system frequently (Q1 = 3.21) and considered the system user-friendly (Q3 = 3.41). Furthermore, most participants believed that they could quickly learn and operate the system (Q7 = 3.54), demonstrating that the system achieved relatively good performance in terms of usability and learnability.

However, some limitations were identified in the dimensions of complexity and technical support requirements. The results showed that participants had relatively low perceptions of system complexity (Q2 = 1.07, reverse-scored to 3.93) and technical support requirements (Q4 = 0.95, reverse-scored to 4.05), indicating that further improvements could be made in simplifying the interaction process and reducing the technical threshold.

To further investigate users' acceptance and perception differences across different dimensions, this study classi-

fied the ten evaluation items in the questionnaire into three key perception dimensions: usability, complexity, and user-friendliness. The usability dimension includes Q1, Q3, and Q7, focusing on users' overall evaluation of system practicality and ease of learning. The complexity perception dimension consists of Q2, Q4, and Q10, reflecting users' perception of system complexity and the need for technical assistance. The user-friendliness dimension contains Q5, Q6, Q8, and Q9, which evaluates users' perception of functional integration, consistency, and overall confidence and comfort during system operation.

To examine whether statistically significant differences existed among users' evaluations of different dimensions, this study employed Paired-Samples T-Tests (PST). Since the same participants evaluated multiple dimensions of the system, paired comparisons were conducted to analyze differences among usability, learnability, and functional integration. This statistical method is appropriate for the experimental design, as it compares the mean differences between two related conditions within the same group of participants. The test statistic is calculated as follows:

$$t = \frac{\bar{D}}{s_D / \sqrt{n}} \quad (1)$$

	disagree ← → agree	b question	Mean Score	Transformed Score
1. I believe I would be inclined to use this system frequently.		Q1	3.21	3.21
2. I find this system overly complex.		Q2 (Reverse)	1.07	3.93
3. I consider this system remarkably user-friendly.		Q3	3.41	3.41
4. I require technical support to operate this system effectively.		Q4 (Reverse)	0.95	4.05
5. The integration of features within the system is seamless.		Q5	2.73	2.73
6. I perceive substantial inconsistencies among the system's functionalities.		Q6 (Reverse)	1.75	3.25
7. Most individuals can swiftly master the use of this system.		Q7	3.54	3.54
8. Interacting with this system feels excessively cumbersome.		Q8 (Reverse)	1.64	3.36
9. I feel highly confident when utilizing this system.		Q9	3.26	3.26
10. A significant amount of prior learning is necessary to operate this system.		Q10 (Reverse)	0.66	4.34
		SUS Score	55.55	87.7

Figure 23 | SUS survey questionnaire (a) and score results (b)

Table 1 | Average scores on survey questions by dimension

Comparing Dimension	Mean Difference	T-value	P-value	Significance Judgment
Usability (3.35) vs. Learnability (3.92)	-0.57	-7.01	1.40×10^{-8}	Significant difference
Usability (3.35) vs. Integration (3.30)	0.05	0.55	0.588	No significant difference
Learnability (3.92) vs. Integration (3.30)	0.62	5.13	7.06×10^{-6}	Significant difference

$\bar{D}$ denotes the mean of the paired differences; s_d denotes the standard deviation of the paired differences; n is the sample size (43 in this experiment); the significance level is set at α .

To evaluate the practical application effect and public experience of the system, the System Usability Scale (SUS) was used to quantitatively assess its usability, learnability, and functional integration.

Through statistical analysis of the questionnaire data from 43 public participants, the results showed that the learnability dimension score was significantly higher than that of usability (mean difference -0.57, $t = -7.01$, $p < 0.001$) and functional integration (mean difference 0.62, $t = 5.13$, $p < 0.001$), indicating that users generally found the system easy to learn and master. Meanwhile, there was no significant difference between usability and functional integration (mean difference 0.05, $t = 0.55$, $p = 0.588$), suggesting that the system performed relatively well in terms of operational convenience and functional coordination.

This evaluation result demonstrates that the narrative axis based on "natural symbiosis - craftsmanship - maritime silk trade" has constructed an immersive virtual reality digital display system integrating AIGC image generation and VR technology, which can effectively reduce the learning cost of intangible cultural heritage (ICH) display, provide potential support for users' cultural understanding and emotional engagement, although further empirical studies are still required to verify its impact on cultural identity formation and emotional responses. The relatively lower score of functional integration indicates that there is still room for im-

provement in multimodal interaction and content organization. This result may be related to the complexity of integrating multiple functional modules, including AIGC-generated visual content, cultural information presentation, and interactive exploration processes. For users who are unfamiliar with Xiangyunsha culture, the simultaneous presentation of multiple information dimensions may increase cognitive load and affect the perceived coherence of the overall interaction experience. Future optimization can focus on simplifying the interaction hierarchy, improving information organization, and introducing adaptive guidance mechanisms to enhance the coordination between different functional modules. Overall, this system provides a practical and feasible demonstration solution for the digital display design of intangible cultural heritage skills, which is conducive to promoting the modern inheritance and innovative dissemination of traditional culture. Furthermore, the proposed digital display approach provides new possibilities for overcoming geographical limitations and expanding the dissemination pathways of Xiangyunsha weaving techniques through digital platforms.

Conclusion

This research, based on the theory of image narrative and the application of virtual reality technology, has constructed a methodological framework for the digital display of the Xiangyunsha dyeing and finishing techniques. It proposes a threefold narrative axis of "natural symbiosis - craftsmanship - maritime silk trade", systematically presenting the

comprehensive cultural value of Xiangyunsha in terms of ecological foundation, artistic features, and cultural flow. Through AIGC-assisted image generation and the extraction of Lingnan style semantics, combined with immersive space modeling and interaction design in virtual reality, the research has broken through the traditional single model of intangible cultural heritage display that mainly relies on physical exhibitions, and explored an innovative system of intangible cultural heritage digital display design that integrates image narrative, sensory experience, and value perception.

The construction and digital presentation of the image narrative axis, using virtual display scenarios, not only achieve the full-process image restoration and contextualized narration of the Xiangyunsha dyeing and finishing process but also, through feasibility assessment, play a positive role in promoting public emotional participation and cultural understanding. This helps intangible cultural heritage move from "visible" to "understandable", enhancing the visual communication power and public recognition of intangible cultural heritage techniques, and realizing the transformation from "exhibition-based preservation" to "immersive activation".

In conclusion, the digital display design system for Xiangyunsha dyeing and finishing techniques links image narrative with immersive experience systems, providing an innovative model that integrates technological innovation and cultural dissemination for similar intangible cultural heritage projects. It also offers a reference sample with theoretical value and practical significance for the inheritance and transformation of intangible cultural heritage under the background of the Digital China strategy. Future related research can further explore multi-sensory integration paths and AI-driven narrative mechanisms, deepening the communication effectiveness of digital intangible cultural heritage in the construction of cultural identity.

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Study on the Relationship Between Urban Rail Transit and Urban Tourism: A Case Study of the Top Ten Cities in China

Ruiping Zhu^{1,2}, Haojie Chen^{1,2}, Ran Peng^{1,2,*}

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Abstract: In order to explore the intrinsic relationship between rail transit and urban tourism, this study employs a combination of literature review, expert consultation, and analytic hierarchy process. An online and offline dual-channel survey was conducted through the Credamo platform, collecting 1,253 valid responses. The sample covers different age groups, income levels, and regions, and the survey includes six core dimensions. The survey results show: 1) The 21–40 age group has the highest tourism consumption capacity and travel tendency; 2) Income is positively correlated with willingness to travel, while the correlation becomes negative among high-income, busy groups; 3) Groups relying on the subway for daily transportation are more likely to choose it for tourism and prefer accommodation near subway stations; 4) The development level of the subway network is an important factor in destination choice; 5) Empirical analysis of 10 sample cities shows that tourists' subway use is strongly correlated with subway mileage, while satisfaction is moderately correlated with transfer factors, confirming a significant association between rail transit and tourism. This study also incorporates urban cultural resources, tourism appeal, population density, and ground transportation into its theoretical framework, emphasizing that rail transit does not influence urban tourism independently. Instead, by improving the accessibility of cultural tourism resources, optimizing visitors' spatial movement patterns, and reducing travel time costs, it interacts with the distribution of urban cultural spaces and tourism resources to shape visitors' behavioral decisions. Based on these findings, the study concludes that a multidimensional interactive relationship exists between urban rail transit and urban tourism, providing theoretical and practical references for rail transit network optimization, cultural tourism resource allocation, and urban tourism governance.

Keywords: Rail transit; Urban tourism; Questionnaire survey; Correlation; Tourism resource allocation



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Introduction

As an important component of the modern urban transportation system, rail transit not only serves the daily commuting needs of urban residents, but has also gradually become a vital form of infrastructure connecting tourist attractions, historic districts, commercial centers, cultural venues, and public leisure spaces. As urban tourism shifts from traditional sightseeing toward cultural experience, leisure consumption, and integrated spatial experience, the influence of rail transit on urban tourism is no longer confined to the level of “transport accessibility”; rather, it has become fur-

ther embedded in tourists' perception, selection, and consumption of urban cultural resources.

As the core of modern urban transportation, rail transit integrates into the urban transport system with characteristics of green safety, speed, and convenience. It is not only the key link to connect cultural and tourism resources and stimulate consumption [1], but also aligns with the logic of traffic optimization and the reshaping of the regional tourism flow structure. Among these, the subway can alleviate surface congestion and enhance transportation efficiency. By relying on its routes to connect scenic spots, business districts, and

¹ School of Civil Engineering and Architecture, Wuhan Institute of Technology, Wuhan 430074, China; ² Wuhan Red Culture Research Center, Wuhan 430056, China.

* Corresponding author. Email: pengran@wit.edu.cn.

other cultural tourism nodes, it fosters consumer clusters and empowers the integrated development of culture and tourism. However, influenced by the differences in network planning and resource endowment, the spatial correlation between the subway and cultural tourism nodes exhibits significant regional differentiation characteristics [2].

From the perspective of cultural tourism, the attractiveness of urban tourism derives not only from natural landscapes or commercial consumption spaces, but also from cultural resources such as museums, historic and cultural districts, intangible cultural heritage exhibition spaces, urban landmarks, and art galleries. By shortening the temporal distance required for tourists to reach these cultural resources and reducing the cost of cross-regional visits, rail transit can significantly enhance tourist accessibility to cultural resources and improve the efficiency of tourism conversion. Therefore, research on the relationship between rail transit and urban tourism should not remain limited to transport mileage and tourists' travel preferences; it should also examine how rail transit influences tourists' access to, experience of, and consumption within urban cultural spaces. There are still some gaps in existing research: first, there is a noticeable lack of studies on the impact mechanism of the subway on urban tourism development and its quantitative evaluation; second, the actual driving effect of rail transit on urban tourism needs further empirical research for validation. Third, although some studies have examined the influence of rail transit on the spatial structure of tourism, they insufficiently incorporate "culture" as a core element of urban tourism and rarely discuss how rail transit affects tourist behavior by connecting cultural attractions, historic districts, and consumption spaces. Fourth, in empirical analysis, some studies tend to directly interpret the correlation between rail transit mileage and tourists' propensity to travel as a causal relationship, while neglecting the effects of control variables such as urban tourism attractiveness, population density, surface traffic congestion, city recognition, and cultural resource endowment. As a result, there is a certain risk of "spurious correlation."

From a historical development perspective, the world's first subway was built in the UK in the 1820s, pioneering underground urban transportation and providing a new path for expanding urban cultural and tourism spaces. In the 1960s, a global wave of subway construction emerged, and countries integrated cultural and tourism resources along subway lines, making it the core carrier for underground space development and the exploration of cultural tourism value. The construction of subways in China started relatively late [3]. In 1961, the first subway in Beijing began construction, and after eight years, a 23.6-kilometer line was completed and put into operation. This marked the beginning of a new era in urban underground transportation in China and laid the foundation for later connecting cultural and tourism resources with rail transit and building distinctive cultural and tourism routes.

From the perspective of functional value, rail transit plays a key role in modern cities. It not only improves urban

transportation but also breaks the limitations of a single mode of travel [4]. It deeply integrates into the urban transportation system, driving economic development, optimizing spatial structure, extending functional boundaries, and improving resource allocation, thus becoming an important support for the integration of culture and tourism. This effect not only aligns with the analysis by Li Jinglong et al. [5] on the deep connection between urban tourism and urban development but also validates Wei Xiao'an's [6] view on the core role of transportation elements in the construction of tourism cities, providing theoretical anchor points for subsequent research. More specifically, the influence of rail transit on urban tourism is mainly reflected in three dimensions. First, at the level of transport accessibility, metro networks can shorten the travel time of tourists among scenic areas, commercial districts, and cultural nodes, thereby improving the efficiency of tourism activities. Second, at the level of spatial organization, rail transit routes and stations influence the scope of tourist activities, enabling originally scattered tourism resources to be incorporated into continuous urban tourism routes. Third, at the level of cultural experience, rail transit enhances the accessibility of cultural venues, historic districts, and urban public cultural spaces, strengthening tourists' depth of perception of urban culture and thereby influencing tourism satisfaction and destination choice.

Based on the above theoretical and practical foundation, foreign scholars have conducted empirical research on the relationship between the two. Kormoss IBF [7], focusing on Northwestern Europe, revealed the potential impact of future transportation patterns on the tourism industry by examining the interaction between transportation and tourism. Becker C and George B P [8], using the Madrid Metro as a case study, empirically demonstrated that the layout of subway lines and station settings have significant suburban effects, promoting population aggregation, enhancing land-use efficiency, and driving the integration of tourism resources and industrial prosperity, providing a reference from outside the country.

Domestic scholars, on the other hand, focus on local urban cases for in-depth research from multiple perspectives. Hu Jiangchuan [9], based on cultural capital theory, proposed that the subway has transcended its role as a mere transportation tool and has become a composite carrier with functions of transportation, industrial clustering, and cultural bearing, providing core support for the prosperity of tourism. Bian Xianhong and Weng Biyun [10], using Hangzhou as a case study, confirmed that improving the accessibility of tourism peripheral areas can stimulate demand, drive the extension of growth poles, and empower the construction of new urban districts. Zhang Ning and Zhang Xiaoling [11], using Nanjing as a case study, systematically analyzed the empowerment mechanism of the subway on the tourism industry from the dimensions of spatial integration, scope expansion, product innovation, and demand adaptation. Overall, however, existing studies have mostly examined rail transit from the perspectives of transporta-

tion infrastructure construction, accessibility improvement, and tourism mobility efficiency, while discussions of the relationship between rail transit and urban cultural tourism resources remain relatively insufficient. Particularly at the empirical level, further improvements in research design and econometric modeling are still needed to distinguish the effect of rail transit itself from the combined effects of factors such as urban tourism attractiveness, population size, cultural resource density, and surface transportation conditions.

In conclusion, as the degree of integration between urban rail transit and urban tourism continues to deepen, related theoretical systems become more refined, and empirical research methods are constantly optimized, the study of the impact of the subway on urban tourism development has become a hot topic in academia. Existing research has conducted extensive exploration in this area, accumulating rich theoretical achievements and empirical experience, providing a solid foundation for this study. However, it also highlights the research gaps mentioned earlier: existing studies still have significant shortcomings in analyzing the impact mechanism of the subway on urban tourism development and in its quantitative evaluation. The actual driving effect of rail transit on urban tourism also requires deeper empirical research for verification. This clarifies the core entry point and research direction for this study. Therefore, this paper takes ten major Chinese cities—Beijing, Shanghai, Guangzhou, Shenzhen, Chengdu, Wuhan, Chongqing, Xi'an, Nanjing, and Hangzhou—as its research objects. By combining questionnaire survey data with city-level indicators, it focuses on analyzing the influence of rail transit on tourists' transportation choices, accommodation preferences, tourism experiences, and destination choices. Meanwhile, based on existing variables such as metro mileage and transfer coefficients, this paper further emphasizes the importance of control factors including urban cultural tourism resources, urban tourism attractiveness, and the transportation environment, in order to enhance the explanatory power and rigor of the research conclusions. Through this study, references can be provided for urban rail transit planning and tourism resource development, while also offering supplementary insights into transportation-tourism interaction research in the context of urban culture-tourism integration.

Research Methods and Data

Research methods

This study employs two core research methods:

First, the questionnaire survey method. Targeting groups from different regions, age ranges, income levels, and tourism experiences, a questionnaire survey is conducted through both online and offline channels via the Credamo platform to collect basic research data.

Second, the data analysis method. The survey data is subjected to statistical analysis to clarify the general relationship between rail transit and urban tourism. At the same

time, regional differentiated indicators are integrated to deeply explore the core influencing factors.

Third, the analytic hierarchy process is applied. In this paper, the analytic hierarchy process is specifically used to determine the indicator weights for evaluating the value of rail transit in influencing urban tourism. Based on the research objectives, an evaluation system consisting of a “target layer–criterion layer–indicator layer” is constructed.

Fourth, the literature analysis method is adopted. By reviewing relevant studies on urban tourism, transport accessibility, cultural capital, tourism spatial structure, and rail transit network effects, this paper provides theoretical support for the construction of the research framework.

Fifth, the expert consultation method is used. During the process of questionnaire design and indicator system construction, this paper solicits opinions from experts in relevant fields, focusing on whether the indicator settings are reasonable, whether the questionnaire items can reflect tourists' actual behavior, and whether the AHP evaluation indicators are hierarchical and operational. The results of expert consultation are mainly used to optimize the questionnaire structure, revise the wording of indicators, and provide a basis for the subsequent construction of the judgment matrix ([Figure 1](#)).

Research subjects

The survey on the impact of rail transit on urban tourism included 1,253 respondents from different age groups and regions across provinces and cities. The respondents have visited cities such as Beijing, Shanghai, Guangzhou, Shenzhen, Chengdu, Wuhan, Chongqing, Xi'an, Nanjing, and Hangzhou, with the purpose of tourism. The sample selection is based on the following criteria:

1. The above-mentioned cities (as shown in [Figure 2](#)) are representative examples in China with leading rail transit mileage and visitor reception volume, having established or progressively perfected their rail transit systems. By selecting visitors as the survey subjects, the study essentially focuses on cities with high-level integration of rail transit and cultural tourism, ensuring the representativeness and typicality of the sample. At the same time, these ten cities are highly representative in terms of historical and cultural resources, urban commercial vitality, tourism reputation, and rail transit development. For example, Beijing, Xi'an, Nanjing, and Hangzhou possess prominent historical and cultural tourism resources, while Shanghai, Guangzhou, Shenzhen, Chengdu, and Chongqing are typical examples in terms of modern urban tourism, commercial consumption, and public transportation network construction. Therefore, using these cities as sample cities can effectively reveal the differences in the impact of rail transit on tourism activities across different types of cities.
2. Different age groups were selected to explore the differentiated impact of age on respondents' perception of the value of rail transit's empowerment of urban tourism.

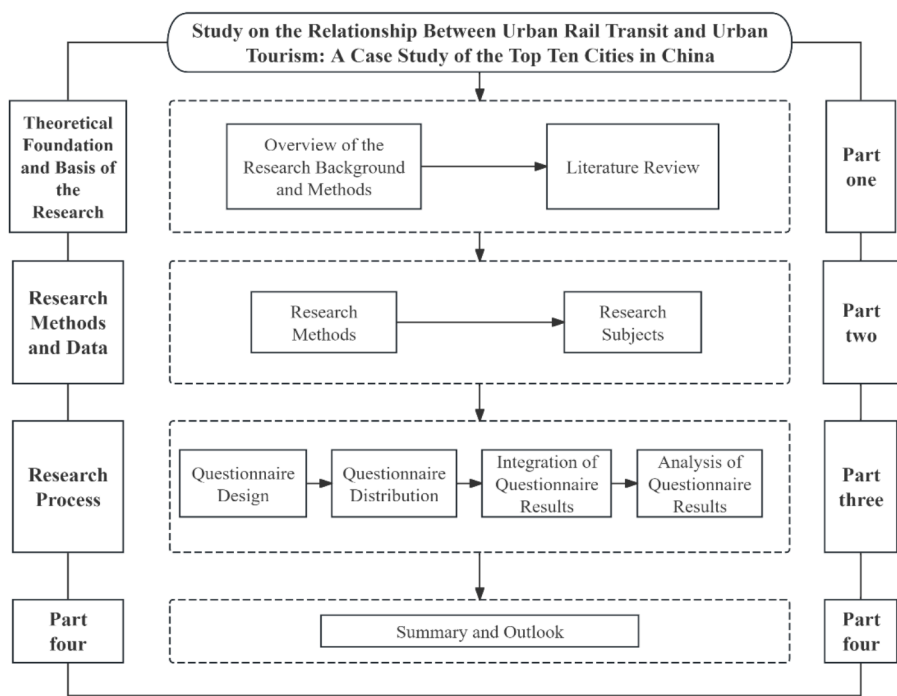


Figure 1 | Research Framework

Age affects not only tourists' physical conditions and tourism consumption preferences, but also their adaptability to metro ticket purchasing, transfers, walking connections, and other travel procedures. Therefore, this paper treats age as an important individual characteristic variable to analyze differences among age groups in their tendency to use rail transit for tourism purposes.

3. Various income groups were included to verify the influence of income differences on the perception of this value. Income level affects tourists' trade-offs among travel costs, accommodation location, tourism comfort, and time efficiency. In general, middle- and high-income groups may pay greater attention to travel efficiency and accommodation convenience, whereas lower-income groups may be more concerned about transportation costs. Therefore, incorporating income as a variable in the analysis helps explain differences in how different tourist groups perceive the tourism value of metro systems.
4. Different origin groups were incorporated to explore the potential role of the rail transit support situation in the respondents' hometowns on their dependence on rail transit during their tourism activities and related value perceptions. Whether a respondent's place of residence has a rail transit system influences their daily travel habits and familiarity with metro use. Respondents who have long lived in cities with metro systems are often more likely to develop metro dependence and habitual

metro use, whereas respondents whose places of residence lack metro systems may be less inclined to choose the metro during tourism because they are unfamiliar with procedures such as ticket purchasing, transfers, and route identification. Therefore, this variable can serve as an important control factor for explaining differences in tourists' metro usage.

Variable selection and model design

This paper regards metro mileage as one of the important explanatory variables influencing tourists' propensity to choose the metro, and conducts a comprehensive analysis by incorporating factors such as urban tourism attractiveness, population density, surface traffic conditions, and cultural tourism resources.

Explained variables

This paper establishes two core explained variables. The first is tourists' propensity to choose the metro, denoted as Y_1 . This variable is represented by the proportion of tourists in each sample city who choose the metro as their primary mode of transportation during tourism, and is used to measure tourists' degree of dependence on the metro in the process of urban tourism. The second is tourists' satisfaction with the metro, denoted as Y_2 . This variable is represented by the proportion of tourists in each sample city who report being satisfied or very satisfied with their metro travel experience, and is used to measure tourists' subjective evaluation of the service quality of rail transit for tourism purposes.

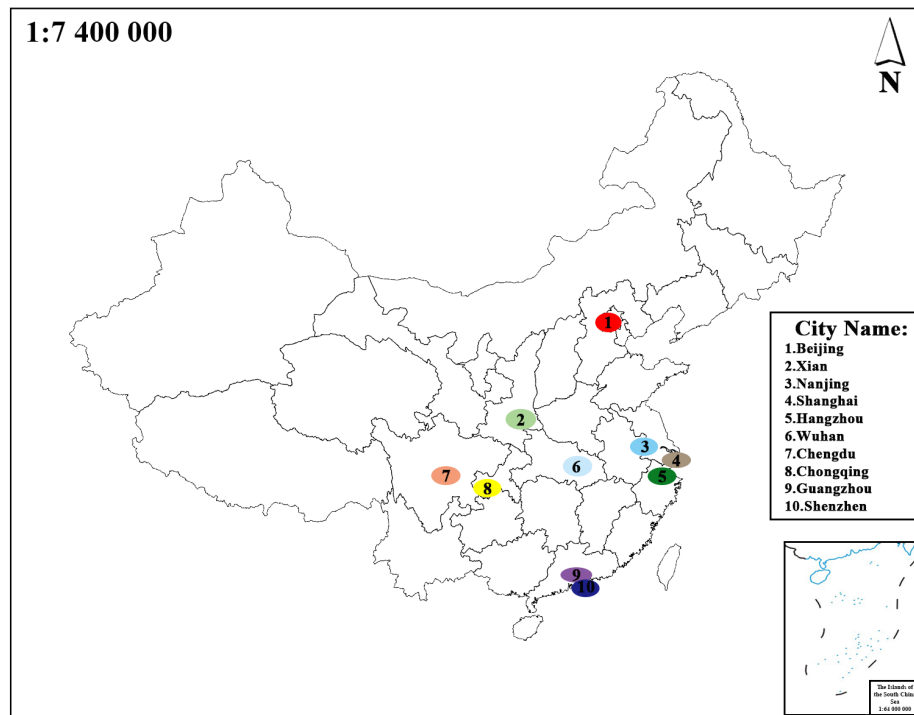


Figure 2 | Map showing the locations of the top ten cities

Core explanatory variables

This paper sets two core explanatory variables. The first is metro operating mileage, denoted as X_1 , which is used to reflect the scale of the urban rail transit network. The longer the metro operating mileage, the wider the route coverage, and the greater the convenience for tourists in reaching scenic areas, commercial districts, and cultural venues. The second is the transfer coefficient, denoted as X_2 , which is used to reflect the transfer structure and route connectivity of the urban rail transit network. An appropriate number of transfer nodes can improve connectivity efficiency among routes; however, excessive transfer complexity may also increase tourists' travel burden. Therefore, its effect on satisfaction may not follow a simple linear relationship.

Control variables

To avoid mistakenly attributing a city's inherent attractiveness to the influence of rail transit, this paper further introduces the following control variables. First, urban tourism attractiveness, denoted as C_1 , can be approximated by the number of tourist visits, the scale of tourism reception, or the number of respondents in the questionnaire who have visited the city. Cities with stronger tourism attractiveness may obtain higher tourist arrivals and travel frequency even when their rail transit conditions are only average. Second, the level of cultural tourism resources, denoted as C_2 , can be measured by the density of major cultural attractions, historic districts, museums, cultural landmarks, and other resources in the city. The richer the cultural tourism resources, the more evident the supporting role of rail transit

in facilitating tourists' spatial mobility and cultural experience. Third, population density, denoted as C_3 , affects urban traffic congestion, metro passenger-flow pressure, and tourists' travel comfort, and may therefore influence both whether tourists choose the metro and how they evaluate their satisfaction with it. Fourth, surface traffic conditions, denoted as C_4 . When surface road congestion is severe, tourists are more likely to choose the metro, which offers relatively stable travel times; conversely, in cities where surface transportation is more convenient, tourists' dependence on the metro may decline. Fifth, metro conditions in the place of residence, denoted as C_5 , are used to indicate whether respondents have long lived in a city with a metro system, thereby controlling for the influence of daily travel habits on tourism transportation choices.

Model specification

In the analysis of tourists' propensity to choose the metro, this paper constructs the following basic model:

$$Y_1 = \alpha_0 + \alpha_1 X_1 + \alpha_2 C_1 + \alpha_3 C_2 + \alpha_4 C_3 + \alpha_5 C_4 + \varepsilon \quad (1)$$

where Y_1 represents tourists' propensity to choose the metro, X_1 represents metro operating mileage, C_1 to C_4 respectively represent urban tourism attractiveness, the level of cultural tourism resources, population density, and surface traffic conditions, and ε is the random error term.

In the analysis of tourists' satisfaction with the metro, this paper constructs the following basic model:

$$Y_2 = \beta_0 + \beta_1 X_2 + \beta_2 X_1 + \beta_3 C_2 + \beta_4 C_3 + \beta_5 C_5 + \mu \quad (2)$$

where Y_2 represents tourists' satisfaction with the metro, X_2 represents the transfer coefficient, X_1 represents metro operating mileage, C_2 , C_3 , and C_5 respectively represent the level of cultural tourism resources, population density, and metro conditions in the place of residence, and μ is the random error term.

It should be noted that, since the number of sample cities in this paper is ten, the city-level regression analysis is more exploratory in nature. It is mainly intended to reveal statistical associations and directional characteristics among variables, rather than to conduct causal identification in the strict sense. To improve the robustness of interpretation, this paper combines questionnaire results, descriptive statistics, cross-tabulation analysis, and theoretical mechanisms to make comprehensive judgments, thereby avoiding excessive conclusions based solely on a single regression result.

Research framework and analytical logic

The research framework of this paper can be summarized as four links: "rail transit conditions—tourism resource connectivity—tourist behavioral response—urban tourism effects."

First, rail transit conditions include factors such as metro operating mileage, number of lines, transfer coefficient, station coverage, and ticket-purchasing convenience, which determine the basic conditions for tourists' mobility within the city.

Second, tourism resource connectivity is mainly reflected in the ability of rail transit to connect tourism nodes such as scenic areas, commercial districts, cultural venues, and historic districts. Rail transit does not affect tourism activities in isolation; rather, it exerts its influence by improving accessibility among tourism resources and enhancing the efficiency of their spatial combination.

Third, tourist behavioral response includes whether tourists choose the metro as their primary mode of transportation, whether they tend to stay near metro stations, whether they believe that a well-developed metro network can improve the tourism experience, and their level of satisfaction with metro-based tourism services.

Fourth, urban tourism effects are reflected in the improvement of tourism experience, the expansion of tourism space, the enhancement of cultural resource utilization efficiency, and the release of cultural-tourism consumption potential.

Based on the above logic, this paper argues that the influence of rail transit on urban tourism does not operate through a single pathway. Instead, it is a composite mechanism formed by the joint effects of transport accessibility, accessibility to cultural resources, tourists' travel habits, and the city's overall attractiveness. The subsequent questionnaire analysis and regression analysis will be conducted around this framework.

Questionnaire Survey on the Impact and Value of Rail Transit on Urban Tourism

Questionnaire design

In order to scientifically explore the impact value of rail transit on urban tourism and accurately capture the cognitive and behavioral tendencies of the survey subjects, this study combines multiple research methods, including literature review, expert consultation, and analytic hierarchy process, to systematically design a questionnaire on the impact value of rail transit on urban tourism. The questionnaire serves as the core tool for developing a comprehensive evaluation standard for assessing the impact of rail transit on urban tourism, ensuring the scientific nature of the survey process and the reliability of the results.

The survey adopts a random sampling method to select respondents, with a total of 1,253 participants from different age groups and regions. This approach considers both the heterogeneity and randomness of the sample, providing a reasonable sample base for subsequent analysis of cognitive differences and exploration of influencing factors. The questionnaire content is closely aligned with the core of the study, on one hand collecting basic information such as the geographical coordinates and local cities of the respondents, and on the other hand, designing a series of selective questions focusing on respondents' perceptions and behavioral tendencies regarding the impact of rail transit on urban tourism. Specific questions include whether they prefer to choose the subway as the main transportation mode for tourism, whether they prefer to stay near subway stations, whether they prioritize cities with well-developed subway networks as travel destinations, and their satisfaction with subway tourism services in cities they have visited. At the same time, the questionnaire incorporates respondents' attention to urban cultural resources into the analysis. Specifically, it examines whether respondents tend to visit cultural attractions along metro lines, whether they believe the metro improves the convenience of urban cultural experiences, and whether they pay attention to the connections between metro stations and historic districts, museums, and urban landmarks. This design helps reveal that rail transit does not influence tourism activities merely through "increased mileage," but rather acts on urban tourism experiences by improving the accessibility of cultural resources, reducing the cost of cross-regional visits, and optimizing tourists' itinerary organization. In order to further explore the core driving factors behind the differences in respondents' perceptions of the impact of rail transit on urban tourism, the questionnaire also includes questions about age group, average annual income, and other relevant information to enrich the data collection dimensions.

The questionnaire structure consists of seven core modules: first, the questionnaire title; second, survey instructions; third, basic information of respondents; fourth, perceptions of the relationship between rail transit and urban tourism; fifth, perceptions of accessibility to cultural tourism resources through rail transit; sixth, personal travel prefer-

Table 1 | Indicator System Based on the Analytic Hierarchy Process

Target Layer	Criterion Layer	Indicator Layer
Value of rail transit in influencing urban tourism	Transport accessibility	Metro operating mileage, station coverage, transfer convenience
Value of rail transit in influencing urban tourism	Tourism experience	Degree of time savings, riding comfort, safety, tourist satisfaction
Value of rail transit in influencing urban tourism	Cultural resource connectivity	Number of cultural attractions along metro lines, degree of connection with historic and cultural districts, cultural guidance services
Value of rail transit in influencing urban tourism	Travel cost and service convenience	Fare rationality, ticket-purchasing convenience, accommodation convenience around metro stations

Table 2 | Judgment Matrix for the Criterion Layer

Criterion Layer	Transport Accessibility	Tourism Experience	Cultural Resource Connectivity	Travel Cost and Service Convenience
Transport accessibility	1	2	2	3
Tourism experience	1/2	1	1	2
Cultural resource connectivity	1/2	1	1	2
Travel cost and service convenience	1/3	1/2	1/2	1

Table 3 | Weight Results for the Criterion Layer

Criterion Layer	Weight
Transport accessibility	0.424
Tourism experience	0.227
Cultural resource connectivity	0.227
Travel cost and service convenience	0.122

ences and travel experiences; and seventh, concluding remarks. By adding the module on “perceptions of accessibility to cultural tourism resources,” this study can more comprehensively analyze the role of rail transit in the integration of culture and tourism. The questionnaire structure was systematically refined, and each question was accompanied by clear completion guidelines and detailed explanations to ensure that respondents could accurately understand the requirements and reduce response bias.

To improve the quality of the questionnaire, this study conducted a small-scale pilot test before formal distribution and adjusted the wording of some items based on the feedback received. For example, the question “Do you think the metro contributes to urban tourism?” was further refined into more specific questions, such as “Do you think the metro helps tourists reach scenic areas?”, “Do you think the metro helps tourists reach cultural venues?”, and “Do you think the metro can reduce transfer time between tourist attractions?” This refinement helps reduce respondents’ misunderstanding and improves the interpretability of the questionnaire data.

In the questionnaire design and indicator evaluation, this study further constructs an analytic hierarchy model for assessing the value of rail transit in influencing urban tourism. The model consists of three levels: the target layer, the criterion layer, and the indicator layer.

The target layer is the value of rail transit in influencing urban tourism. The criterion layer includes four dimensions: transport accessibility, tourism experience, cultural resource connectivity, and travel cost and service convenience. The indicator layer includes specific indicators such as metro operating mileage, station coverage, transfer convenience, degree of travel time savings, riding comfort, safety, tourist satisfaction, number of cultural attractions along metro lines, degree of connection with historic and cultural districts, cultural guidance services, fare rationality, ticket-

purchasing convenience, and accommodation convenience around metro stations, as shown in [Table 1](#). Based on expert consultation, this study constructs the judgment matrix for the criterion layer, as shown in [Table 2](#). After calculation, the weight results for the criterion layer are presented in [Table 3](#).

The maximum eigenvalue of the judgment matrix is approximately 4.010, the consistency index, CI, is approximately 0.0035, and the consistency ratio, CR, is approximately 0.0038, which is less than 0.10. This indicates that the judgment matrix passes the consistency test and that the weight results have an acceptable level of rationality. The weight results show that transport accessibility remains the primary factor through which rail transit influences urban tourism. However, the weights of cultural resource connectivity and tourism experience are equal, indicating that the role of rail transit in urban tourism is reflected not only in “whether tourists can reach destinations,” but also in “whether rail transit can better connect cultural resources and improve the tourism experience.”

Questionnaire distribution

Content of the questionnaire distribution

The main content of this questionnaire focuses on three core data collection modules, as detailed below:

1. Basic Information Module of Respondents: This module collects basic demographic information from the respondents, including gender, occupation, age, average annual income, and the city of residence. This data supports the subsequent exploration of cognitive differences in the impact of rail transit on urban tourism across different groups.
2. Perception of Rail Transit and Urban Tourism Module: This module focuses on respondents’ perceptions and

behavioral tendencies regarding the relationship between rail transit and urban tourism. It includes core content such as the evaluation of the importance of the subway in urban tourism, whether they prefer to choose the subway as the primary transportation mode for urban tourism, whether they prefer to stay near subway stations, and whether they tend to choose cities with well-developed subway networks as travel destinations.

3. **Tourism Travel Experience Module:** This module primarily investigates respondents' travel-related experiences, including the cities they have visited for tourism, whether they have used rail transit during their tourism activities in those cities, and their evaluation of the convenience of the city's rail transit system.
4. **The cultural tourism resource perception module** focuses on respondents' perceptions of the relationship between the metro and urban cultural tourism resources. This includes whether the metro improves the convenience of visiting cultural attractions, whether it enhances respondents' willingness to visit urban historic and cultural districts and cultural venues, and whether they believe that the distribution of cultural resources along metro lines influences their tourism route planning.

Based on the previous support from literature review and expert consultation methods, the tourist survey questionnaire on the impact of rail transit on urban tourism has been highly endorsed by experts in terms of content design, structural rationality, and overall conception. This indicates that the questionnaire has high validity and is ready for formal distribution. During the expert consultation process, some experts pointed out that urban tourism is not influenced solely by transportation conditions, but also by factors such as city recognition, scenic attraction appeal, cultural resource density, and the level of commercial services. Therefore, in the subsequent analysis, this paper does not treat metro mileage as an independent decisive factor. Instead, it regards metro mileage as one important variable influencing tourist behavior and interprets it in combination with other control variables.

Method of questionnaire distribution

This study uses both online and offline channels for the questionnaire survey. Due to practical space limitations, the data collection is primarily conducted through online QR code surveys. In the implementation process, an electronic questionnaire was designed and published through the Credamo system. Once respondents fill out the survey online, all valid data is collected and integrated through the system's backend.

Data collection was carried out through three methods:

1. Using the QR code generated by the Credamo system to collect questionnaires from respondents in different regions across the country.

2. Distributing paper questionnaires in high-traffic areas that meet the characteristics of the research subjects.
3. Sharing the survey QR code and fill-in link through various online communities and QQ groups to widely collect feedback from tourists.

To enhance the validity and participation rate of the survey, this study relied on the Credamo platform, offering a red envelope incentive to participants who completed the survey. Participants must fully complete the questionnaire in order to receive the red envelope reward at the end of the survey. Additionally, to ensure the authenticity and completeness of the data, mandatory fields and a time-limited submission mechanism were set up to avoid missing content and ensure the standardization of data collection.

During the data cleaning stage, this study established three criteria for excluding invalid questionnaires. First, questionnaires with an obviously short completion time, which could not ensure careful responses, were excluded. Second, questionnaires with clear contradictions among logically related items were removed, such as cases in which respondents had never visited a sample city but nevertheless evaluated their satisfaction with that city's metro system. Third, questionnaires showing highly mechanical or continuously repetitive response patterns were excluded. Through these procedures, the interference of invalid samples with the research conclusions was minimized as much as possible.

A total of 1,300 questionnaires were distributed, with 1,278 returned. After excluding 25 invalid questionnaires, 1,253 valid questionnaires were obtained, including 1,197 electronic questionnaires and 56 paper questionnaires. The effective response rate was 96.38%. According to related research on sociology questionnaire response rates, the minimum acceptable valid response rate for surveys is 90% [12,13]. The effective response rate of this survey is significantly higher than the standard value, meeting the data collection requirements for this study.

In terms of sample structure, the questionnaire covers groups with different ages, income levels, places of residence, and tourism experiences, and can therefore reasonably reflect tourists' tendencies to use rail transit and their subjective evaluations during urban tourism. However, it should be noted that the questionnaire sample still consists of tourists' subjective behavioral data, which may be affected by factors such as recall bias, personal preferences, and impressions of cities. Therefore, in the subsequent analysis, this study combines questionnaire data with city-level rail transit indicators to improve the robustness of interpretation.

Integration of questionnaire results

Analysis of the overall situation of the questionnaire survey

Before officially conducting the questionnaire survey, this study made a forward-looking prediction of the survey

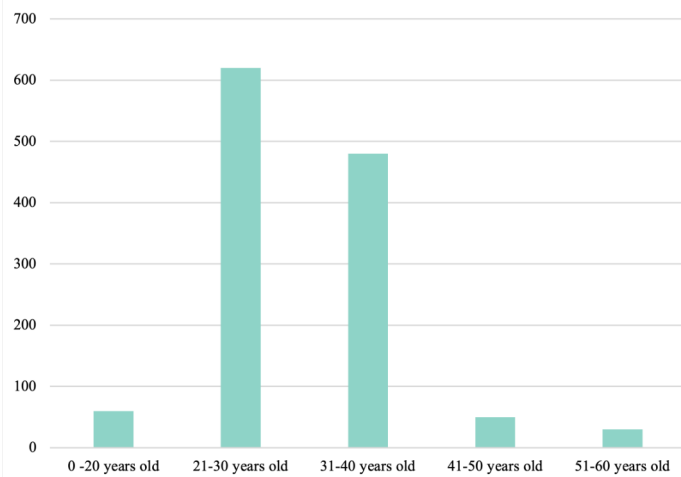


Figure 3 | Age Composition of Survey Respondents

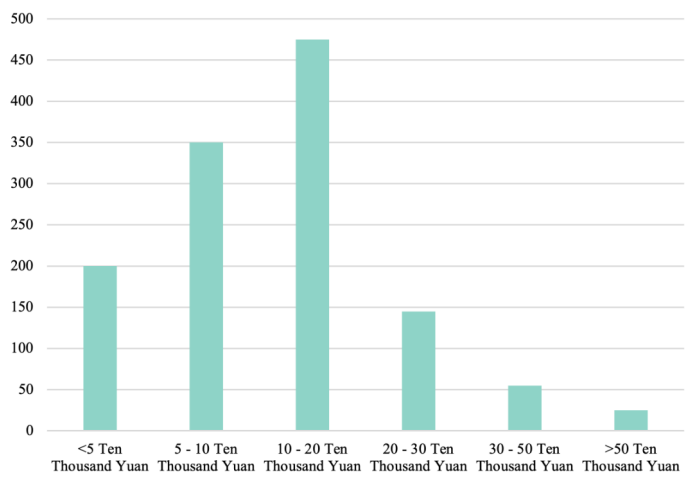


Figure 4 | Composition of Respondents' Average Annual Income

results and conducted a detailed comparison and in-depth analysis between the predicted results and the actual collected data. Overall, the demographic characteristics of the survey respondents were highly consistent with the predicted results, supporting the high scientific and reliability of the data collected, which can support further in-depth research and analysis.

Age of respondents. As shown in [Figure 3](#), the largest proportion of respondents in this survey falls within the 21–30 age group, followed by the 31–40 age group. The number of respondents in these two age groups is significantly higher than the total number of respondents in the 0–20, 41–50, and 51–60 age groups. From a practical consumption perspective, within the 0–60 age range, the 21–30 and 31–40 age groups have a higher tourism consumption capacity, supported by factors such as physical strength, tourism interest, and economic conditions, when compared to other age groups. The age distribution characteristics of the survey respondents are highly consistent with this reality, further confirming that the age structure of the sample is reasonable. However, it should be noted that age structure can only indicate behavioral differences among different age groups in tourism travel, and cannot independently prove a direct causal effect of rail transit on tourism willingness. Therefore, in the subsequent analysis, this study treats age as an individual-level control factor and interprets tourists' propensity to use the metro in combination with variables such as income, metro conditions in the place of residence, and tourism experience.

Income of respondents. As shown in [Figure 4](#), there is a stage-based correlation between the respondents' willingness to travel and their average annual income. For income levels ranging from below 50,000 to the 100,000–200,000 range, the willingness to travel shows a significant upward trend as income increases. However, once the average annual income surpasses 200,000, the willingness to travel ex-

hibits a negative correlation with further increases in income. This characteristic may be closely related to factors such as the busy work schedules of high-income groups and their limited leisure time and discretionary energy for travel. The income variable has a dual influence on rail-transit-based tourism behavior. On the one hand, low- and middle-income groups may attach greater importance to the advantages of metro travel, such as low fares and stable travel times, and may therefore be more inclined to choose the metro as a mode of transportation during urban tourism. On the other hand, higher-income groups may place greater emphasis on comfort and privacy, and may choose taxis, ride-hailing services, or other modes of transport in certain tourism scenarios. Therefore, the relationship between income and the propensity to choose the metro may not be simply linear, but is jointly influenced by time costs, comfort preferences, and differences in tourism modes.

Current residence of respondents. The current residence of respondents is a core research dimension in the tourism travel status questionnaire. This dimension contains rich research information, as an individual's place of residence can directly reflect their lifestyle habits. Different urban locations and living environments shape differentiated cognitive characteristics. This dimension provides important support for the subsequent analysis of cognitive differences regarding the impact of rail transit on urban cultural tourism among different groups. Whether respondents' current city of residence has a metro system is an important variable for explaining tourists' propensity to use the metro. Respondents who have long lived in cities with metro systems are generally more familiar with operational procedures such as route searching, QR-code entry, and transfer planning, and are also more likely to develop metro travel habits. By contrast, respondents whose current cities of residence do not have metro systems may show a relatively lower willingness to choose the metro during tourism due to their lack of daily usage experience. Therefore, metro conditions in the place

Table 4 | Statistical Data of Individuals' Tendency to Use the Subway and Availability of Subway in Their Current City of Residence

Availability of Subway in Current City of Residence	Highly or Somewhat Inclined Group	Other Groups	Total
Cities with subways	509	18	527
Cities without subways	633	93	726

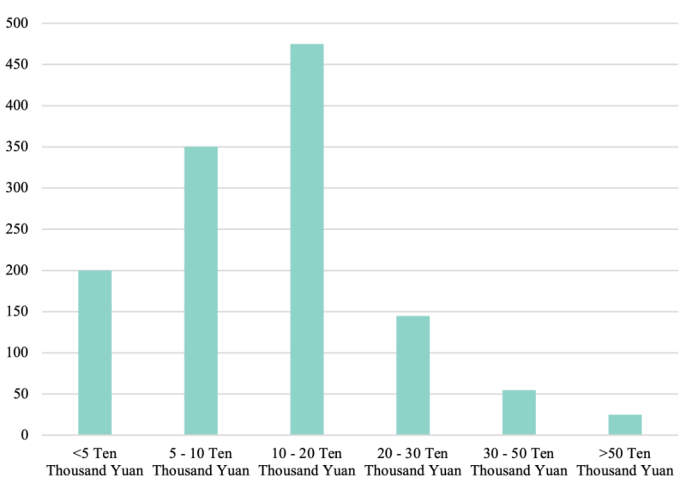


Figure 5 | Distribution of the Tendency to Use the Subway as the Main Mode of Transportation for Urban Tourism

of residence reflect not only differences in transportation infrastructure, but also differences in individual travel habits and travel psychology.

Views on rail transit and urban tourism.
Ference for subway as the main transportation mode for urban tourism. As shown in Figure 5, out of the 1,253 respondents, 666 people (more than half of the sample) prefer to use the subway as the main transportation mode for urban tourism. Among them, 476 respondents are very inclined to choose the subway. In total, these two groups (1,142 respondents) account for over 90% of the sample. This indicates that many respondents prefer the subway as the main transportation mode when traveling to urban tourism destinations. This result suggests that the metro has become a highly recognized mode of transportation among tourists visiting large cities. This is due not only to the advantages of the metro, such as relatively stable fares, predictable travel times, and limited exposure to surface traffic congestion, but also to the fact that metro lines in most sample cities already provide relatively good coverage of core scenic areas, commercial districts, and areas where cultural resources are concentrated. Therefore, tourists' propensity to choose the metro is in fact the result of the combined effects of transport efficiency, route coverage, tourism resource distribution, and individual travel habits.

The group that is either very inclined or somewhat inclined to use the subway as the main mode of transportation for urban tourism consists of 1,142 people. Among them, 509 people (44.5%) reside in areas that have subway lines,

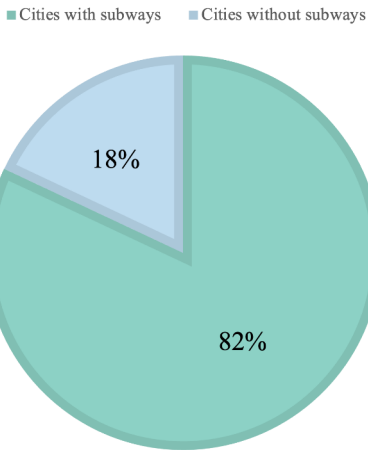


Figure 6 | Distribution of Subway Availability in the Current City of Residence for Individuals Not Inclined to Choose the Subway

while 633 people (55.5%) live in areas without subway lines.

Table 4 statistics show that among the respondents living in cities with a subway, 96.5% are highly or somewhat inclined to use the subway as the main mode of transportation for urban tourism. In contrast, among respondents living in cities without a subway, this inclination is 87.1%, a difference of 9.4 percentage points, with the latter being significantly lower than the former.

As shown in Figure 6, in this study, there are 17 respondents who are not inclined or completely not inclined to choose the subway. Among them, 14 live in cities without a subway, accounting for much of this group.

It can be inferred that people living in cities with subways have developed varying degrees of dependency on subway travel in their daily lives. Therefore, when choosing the main mode of transportation for urban tourism, they are more inclined to use the convenient and efficient subway. On the other hand, individuals who are not inclined to use the subway have no subway travel experience in their daily lives and have not developed this travel habit or dependency. As a result, their inclination to choose the subway as the main mode of transportation for urban tourism is significantly lower than that of the former group. However, in drawing conclusions, this paper should avoid directly interpreting "whether the current city of residence has a metro system" as the sole cause. More accurately, there is a clear correlation between whether the current city of residence has a metro system and tourists' propensity to choose the metro during tourism. This relationship may operate through mediating

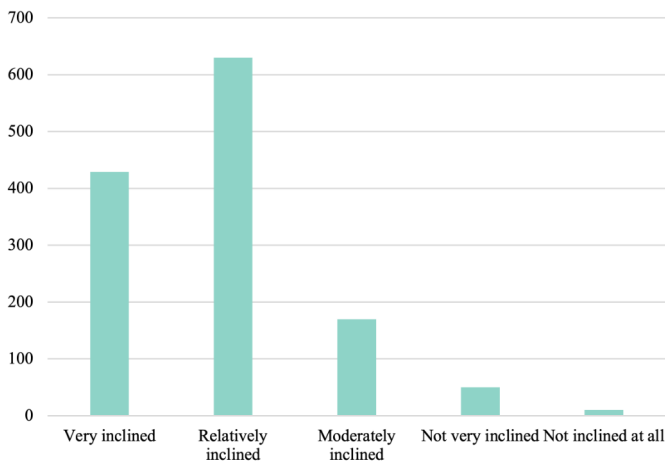


Figure 7 | Distribution of the Number of People Inclined to Stay Near Subway Stations

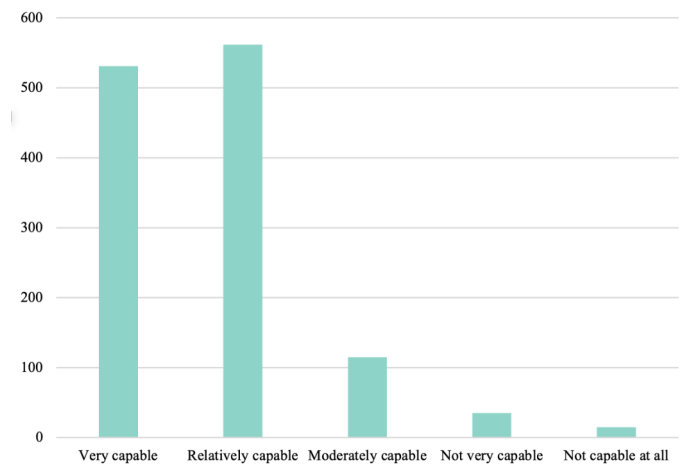


Figure 8 | Distribution of the Number of People Who Believe That Cities with a Developed Subway Network Enhance the Tourism Experience

factors such as daily travel habits, familiarity with metro operations, and perceptions of metro safety and convenience.

Tendency to choose accommodation near subway stations. As shown in [Figure 7](#), among the 1,253 respondents, 630 are somewhat inclined to stay near a subway station, accounting for more than half of the sample; 429 are highly inclined to this choice. The total of these two groups is 1,059, accounting for over 80% of the total respondents. This result further confirms that the vast majority of respondents have a high dependency on rail transportation in urban tourism, and therefore tend to choose accommodations near subway stations to reduce the time cost of traveling to the subway station. This also reflects the group's dependency on subway travel from the perspective of accommodation choices during urban tourism. From the perspective of urban tourism spatial organization, tourists' preference for accommodation near metro stations indicates that rail transit stations influence not only tourists' transportation choices, but also their accommodation location choices and tourism route planning. Areas around metro stations often have high accessibility and a concentration of service facilities, which can help tourists improve the efficiency of moving between attractions within limited travel time. Therefore, the impact of rail transit on urban tourism does not occur only "during travel," but also extends to accommodation choices, consumption spaces, and the radius of tourism activities.

The effect of subway network development on enhancing urban tourism experience. As shown in [Figure 8](#), among the 1,253 respondents, 562 believe that cities with a developed subway network can better enhance the tourism experience, accounting for more than half of the sample. 531 respondents think such cities can greatly enhance the tourism experience. The combined total of these two groups is 1,093, which makes up over 80% of the total respondents. This result further confirms that many respondents recognize that

"a developed subway network has a positive effect on enhancing the urban tourism experience."

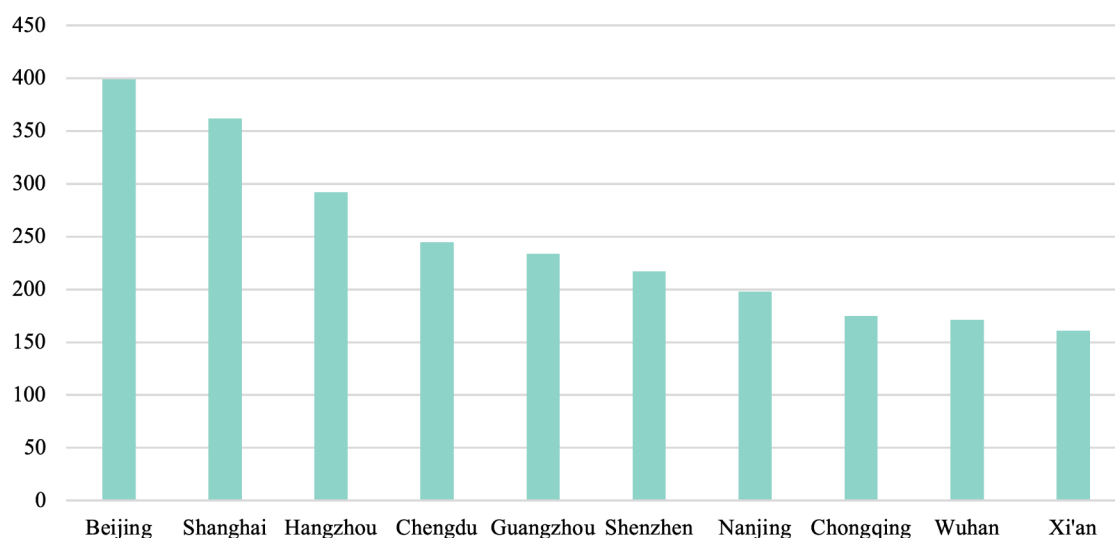
It can be inferred that the development level of the subway network has become an important factor when people choose urban tourism destinations. A well-developed rail transportation network can effectively improve the travel efficiency between various tourist attractions in the city, significantly reducing both the time and economic costs of travel. Furthermore, the improvement of tourism experience brought about by a well-developed metro network is mainly reflected in three aspects. First, it improves the connection efficiency among scenic areas, enabling tourists to visit multiple attractions or cultural nodes within a relatively short period of time. Second, it reduces tourists' dependence on unfamiliar urban road traffic and lowers the uncertainty caused by problems such as traffic congestion, detours, and parking difficulties. Third, it enhances the overall accessibility of urban tourism spaces, allowing cultural tourism resources in peripheral urban areas or non-core areas to attract greater tourist attention.

Perceptions of rail transit and cultural tourism resources. This dimension focuses on whether tourists believe that the metro improves the convenience of reaching museums, historic and cultural districts, urban landmarks, and cultural-commercial districts, as well as whether they arrange cultural tourism routes according to metro lines.

From a theoretical perspective, the tourism value of urban cultural resources depends not only on the reputation of the resources themselves, but also on whether tourists can reach them conveniently. If cultural attractions are far from the main transportation network, tourists may give up visiting them due to time costs and transfer complexity, even if they are interested. Conversely, if cultural resources are located along metro lines or in areas with convenient transfers, they are more likely to be incorporated into tourists' itineraries. Therefore, by improving the accessibility of cul-

Table 5 | Ranking of Subway Mileage in China

Ranking	City Name	Number of Rail Lines	Operating Mileage (Kilometers)
1	Beijing	27	836
2	Shanghai	20	831
3	Guangzhou	16	653
4	Chengdu	13	562
5	Shenzhen	16	556
6	Chongqing	12	538
7	Hangzhou	12	516
8	Wuhan	12	488
9	Nanjing	12	460
10	Xi'an	9	310

**Figure 9 | Cities Visited by Survey Respondents Primarily for Tourism**

tural resources, rail transit can enhance the tourism conversion capacity of those resources.

The data from this section can be combined with subsequent city-level cultural resource variables to analyze the relationship among “metro network—cultural resource accessibility—tourist experience.” In this way, the present study can extend from a general analysis of transportation convenience to an analysis of the mechanism of culture-tourism integration.

Analysis of the questionnaire survey for each city

This survey targets the top ten cities in China by subway operating mileage at the end of 2023 [14] (as shown in [Table 5](#)). The study focuses on tourists' travel choices, transportation selection, travel experience evaluation, and reasons for non-subway travel, among other travel experiences. It conducts an integrated analysis of tourists who have visited the above cities, exploring how the differences in subway systems across cities influence tourists' perceptions and dependency on local rail transportation, as well as the causes behind these effects. By integrating the analysis results from each sample city, the study identifies the core fac-

tors influencing tourists' choice of subway as the main mode of transportation in urban tourism. This empirical foundation provides a micro-level perspective for exploring the relationship between rail transportation and urban tourism in this paper.

By integrating the analysis results of each sample city, this study identifies the core influencing factors that affect tourists' choice of the metro as their main mode of transportation during urban tourism. From a micro-level perspective, this provides an empirical foundation for examining the relationship between rail transit and urban tourism.

This study summarizes and analyzes the relevant data of respondents who visited the cities primarily for tourism, as shown in [Figure 9](#). Among all respondents, the largest number visited Beijing, with 399 people; the fewest visited Xi'an, with only 161 people. The number of respondents visiting each sample city is ranked as follows: Beijing (399), Shanghai (362), Hangzhou (292), Chengdu (245), Guangzhou (234), Shenzhen (217), Nanjing (198), Chongqing (175), Wuhan (171), and Xi'an (161). This ranking closely matches the subway operating mileage ranking in [Table 2](#). The fol-

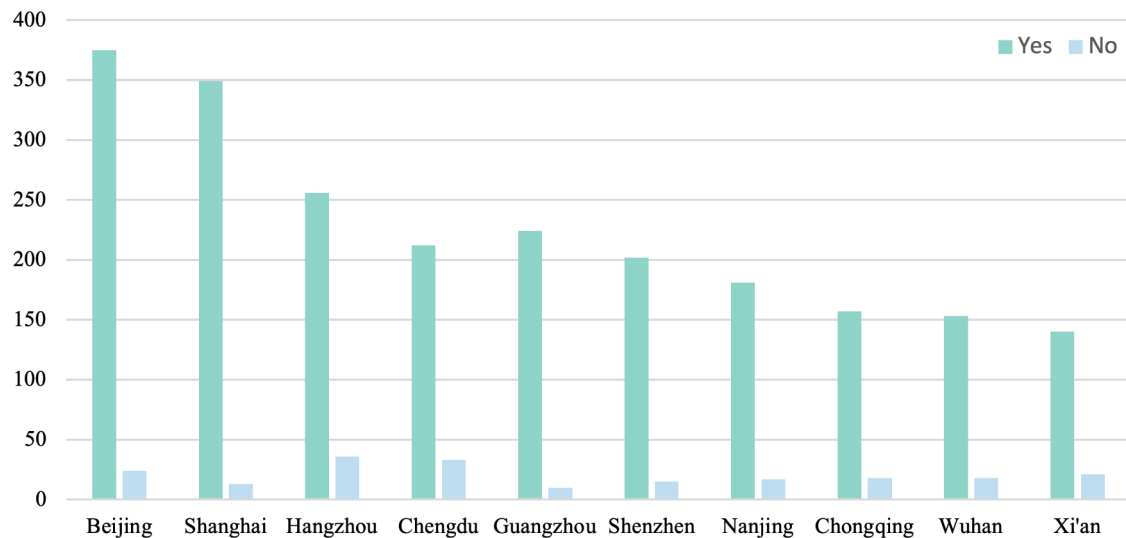


Figure 10 | Whether the Subway is Used as a Mode of Transportation

lowing section will provide a unified comparative analysis of the data from the top ten cities.

In the comparative analysis of cities, this paper focuses not only on metro operating mileage, but also on urban tourism attractiveness, cultural resource endowment, surface traffic conditions, and differences in tourist structure. Differences in metro usage tendencies across cities may be simultaneously influenced by factors such as route coverage, attraction distribution, city size, tourism image, and cultural resource density. Therefore, this paper interprets intercity differences as the result of multiple interacting factors rather than as being determined solely by metro mileage.

As shown in [Figure 10](#), among the respondents included in this survey, the majority chose the subway as their mode of transportation. This indicates that, during their travels in these cities, most tourists prefer to use the subway, a convenient and efficient mode of transportation, as their primary means of getting around. From a city perspective, the attractiveness of the subway as a tourist transportation tool mainly depends on whether its routes cover frequently visited areas by tourists, the convenience of transfers between attractions, the clarity of signage around stations, and whether the subway connects cultural attractions, commercial consumption areas, and accommodation areas. If the subway lines are long but poorly connected to core tourism resources, tourists may still choose other transportation methods; conversely, if the routes effectively link major scenic spots and cultural nodes, even if the operating mileage is not the highest, they may still achieve a high usage rate.

Based on the aforementioned ten city cases, this study further investigates tourists who use the subway as their primary mode of transportation, aiming to assess their overall satisfaction in terms of convenience, comfort, and safety. The survey results, shown in [Figure 11](#), indicate a high overall level of satisfaction among tourists. This data strongly

supports the core argument of this study, which is that, from the perspective of tourist experience, choosing the subway for urban tourism is a rational and feasible travel strategy. The high satisfaction among tourists suggests that rail transit can, to some extent, meet the efficiency and safety demands of urban tourism. However, satisfaction is not solely determined by the number of lines or operating mileage, but also influenced by factors such as transfer complexity, congestion levels, ticketing convenience, in-station signage systems, tourism information services, and the clarity of cultural attraction signage. Therefore, subsequent analysis needs to explain the differences in satisfaction from a multi-variable perspective.

In this questionnaire survey, attention was also paid to respondents who did not choose the metro as their main mode of transportation for urban tourism, and the reasons for their choices were statistically analyzed. The reasons for not choosing the metro vary across different cities, but they are generally concentrated in aspects such as route coverage, crowding levels, transfer efficiency, ticket-purchasing convenience, safety perception, and cost perception. This indicates that, in the view of most tourists, the price, convenience, safety, and other aspects of metro-based tourism in Beijing still require further optimization.

As shown in [Figure 12](#), factors such as metro crowding, time-consuming transfers, unfamiliarity with ticket-purchasing procedures, and insufficient route coverage are important reasons why tourists do not choose the metro as their tourism transportation mode. This result suggests that the expansion of rail transit network scale does not necessarily lead to improved tourist satisfaction. Only when route coverage, transfer organization, riding comfort, and service information are optimized simultaneously can rail transit serve urban tourism more effectively.

This study conducted a systematic statistical analysis of the data from respondents in the ten sample cities who did

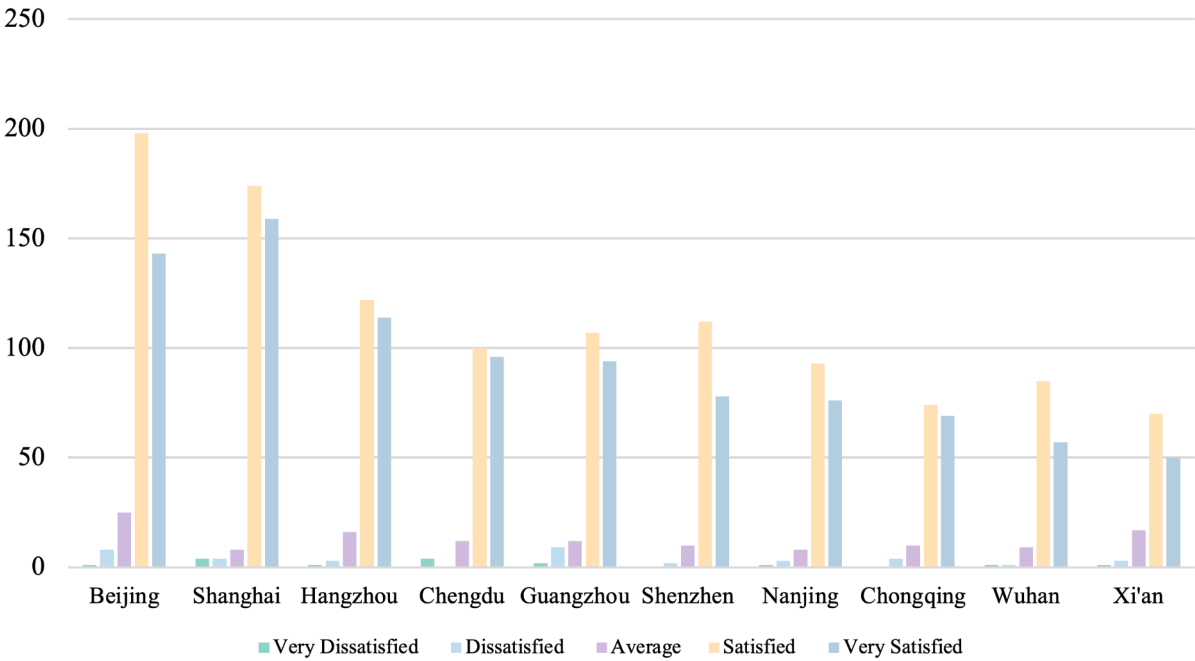


Figure 11 | Satisfaction with the Subway

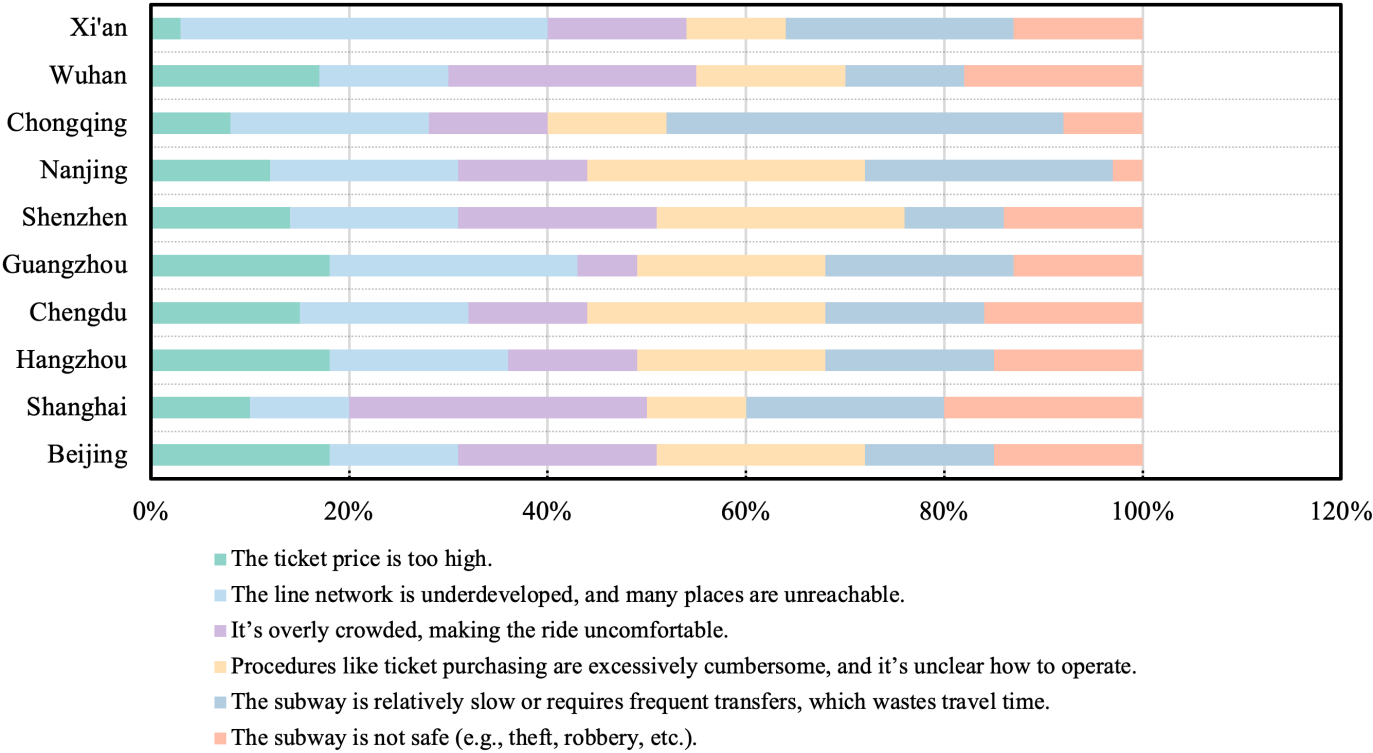


Figure 12 | Reasons for Not Choosing the Subway as a Mode of Transportation

not consider the subway as the main mode of transportation for urban tourism. The results indicate that the core limiting factors affecting respondents' choice of travel modes exhibit both commonalities and significant differences: From a commonality perspective, the core pain points identified by respondents focus on six key dimensions: ticket pricing, safety guarantees, network layout, transfer convenience, operational efficiency, and ticket purchasing experience. These dimensions represent the general shortcomings in the subway systems of the ten cities when adapted to tourism travel scenarios. From a differentiation perspective, the core limiting factors show significant differences across cities, with each city emphasizing different aspects. In addition, insufficient cultural tourism service information is also an issue requiring attention. During metro travel, some tourists may not be aware of whether cultural attractions, historic districts, or distinctive tourism resources exist around a particular station. If wayfinding systems and tourism information prompts inside metro stations are insufficient, even when metro lines are close to relevant resources, their role in directing visitor flows toward cultural tourism resources cannot be fully realized. Therefore, in the future, urban metro systems may strengthen cultural attraction signage, tourist maps, transfer guidance, and multilingual guide services at key stations.

In conclusion, the subway systems in the ten cities still have considerable room for optimization and quality improvement to better meet the demands of tourism travel. It is necessary to target the specific characteristics of each city's core limiting factors, improve infrastructure and service provisions, and further enhance the attractiveness and adaptability of subways in urban tourism contexts. From the perspective of culture-tourism integration, rail transit optimization should not focus solely on the growth of route length, but should also attach importance to the spatial matching relationship between rail transit lines and cultural tourism resources. By improving station coverage of cultural attractions, optimizing connection routes to scenic areas, and improving guidance systems inside and outside stations, rail transit can further release its comprehensive driving effect on urban tourism.

Analysis of the questionnaire results

Integrating the differentiated indicators presented in the previous analysis of the ten cities based on survey results, this study selects the tendency of tourists to choose the subway as their mode of transportation and the satisfaction during the subway journey as the core analysis indicators. Control variables such as urban tourism attractiveness, cultural tourism resource level, population density, surface traffic conditions, and metro conditions in the place of residence are introduced for systematic analysis, in order to identify the key factors influencing the above indicators.

Regression analysis of the tendency to choose the subway for tourism

As shown in the previous analysis, the tendency of tourists to choose the subway as their primary mode of transportation during urban tourism correlates highly with the ranking of subway mileage in various cities. Based on this, the proportion of survey respondents who selected the subway as their primary transportation mode among the total respondents for each city is chosen as the dependent variable Y_i , representing the tourism subway tendency indicator for the i -th city. The independent variable X_i is the city's subway mileage (unit: km), reflecting the differentiated level of subway mileage in each city. A classical overall regression model is constructed [15]. To enhance the rigor of the model, this paper further interprets tourism-related metro usage propensity as the result of multiple interacting factors and constructs an extended model [16]:

$$Y_i = \alpha_0 + \alpha_1 Metro_i + \alpha_2 Tour_i + \alpha_3 Culture_i + \alpha_4 Density_i + \alpha_5 Road_i + \varepsilon_i \quad (3)$$

where Y_i represents the proportion of tourists in city who choose the metro as their main mode of transportation during tourism; $Metro_i$ represents metro operating mileage; $Tour_i$ represents urban tourism attractiveness; $Culture_i$ represents the level of cultural tourism resources; $Density_i$ represents population density; $Road_i$ represents surface traffic conditions; and ε_i is the random error term. The purpose of this model specification is to distinguish the influence of metro mileage itself from the combined effects of factors such as urban tourism attractiveness and cultural resource endowment. For example, in some cities, even if metro mileage is relatively long, the metro usage rate among tourists may still be affected by factors such as the dispersed distribution of scenic areas, complex transfers, or a relatively high proportion of tourists choosing self-driving travel. Conversely, although some cities may not have an absolute advantage in metro mileage, if their major scenic areas and cultural districts are concentrated along metro lines, they may still achieve a relatively high rate of metro use for tourism purposes (Table 6).

As shown in Table 7, the multiple correlation coefficient (Multiple R) for this analysis is 0.759, and the coefficient of determination (R Square) is 0.576. This indicates a strong correlation between tourists' preference for subways and the length of subway routes. The greater the length of subway routes in a city, the more likely tourists are to use the subway as their primary mode of transportation during their visit to that city. However, it should be further noted that an R Square of 0.576 means that metro mileage can explain part of the difference in tourists' propensity to choose the metro, while approximately 42.4% of the difference still needs to be explained by other factors. Therefore, this paper cannot simply equate "longer metro mileage" with "tourists will inevitably be more inclined to choose the metro." Rather, it should be understood as follows: the expansion of metro mileage generally improves the coverage of urban rail transit, and, when interacting with the distribution of scenic areas, cultural resource connectivity, transfer convenience,

Table 6 | Statistical Table of Variables Required for Regression Analysis

City Name	Operating Mileage	Subway Preference	Transfer Coefficient	Satisfaction
Beijing	836	94.0%	1.8199	93.0%
Shanghai	831	96.4%	1.8047	95.4%
Guangzhou	653	95.7%	1.8302	95.7%
Chengdu	562	86.6%	1.7659	92.5%
Shenzhen	556	93.0%	1.7065	94.0%
Chongqing	538	89.7%	1.59	91.1%
Hangzhou	516	87.6%	1.6476	92.2%
Wuhan	488	89.4%	1.584	92.8%
Nanjing	460	91.4%	1.6679	93.4%
Xi'an	310	86.9%	1.5378	85.7%

Table 7 | Regression Distribution Statistics of Subway Preference and Subway Mileage

Regression statistics	
Multiple R	0.759
R Square	0.576
Adjusted R Square	0.524
Standard Error	0.025
Observed Values	10

Table 8 | Confidence Intervals for Correlation Coefficients

Multiple Correlation Coefficient R	Correlation
$R > 0.75$	Strong Correlation
$0.75 > R > 0.5$	Moderate Correlation
$0.5 > R > 0.25$	Weak Correlation
$R < 0.25$	No Correlation

Table 9 | Regression Distribution Statistics of Tourist Satisfaction with the Subway and Transfer Coefficient

Regression statistics	
Multiple R	0.646
R Square	0.417
Adjusted R Square	0.344
Standard Error	0.023
Observed Values	10

and tourists' travel habits, increases the likelihood that tourists will choose the metro.

With the advancement of urbanization in our country, the urban rail transit systems in various cities are gradually being improved and upgraded. The expansion of subway operating mileage mainly reflects the extension of line networks and the broadening of station coverage, laying the foundation for enhancing the convenience and accessibility of rail transit. This optimization can significantly increase tourists' preference for choosing the subway for travel, which validates the rationale behind the correlation between subway mileage and tourists' inclination to choose the subway, completing the logical argument. From the perspective of cultural tourism, the expansion of metro mileage can fully realize its tourism value only when it effectively connects cultural attractions, historic districts, tourism commercial areas, and accommodation areas. Therefore, future rail transit planning should emphasize the coupling between route construction and the spatial layout of cultural tourism resources, rather than simply pursuing growth in operating mileage.

Regression Analysis of Tourist Satisfaction with the Subway

Combining the statistical results of the tourist survey conducted in ten sample cities mentioned earlier, among the tourists who did not choose the subway as their main mode of transportation, inconvenient transfers and crowded carriages are the primary concerns. From the perspective of optimizing rail transit operations, various cities often alleviate congestion and enhance transfer convenience through optimizing transfer coefficients and adding transfer stations, thus improving the passengers' riding experience and laying the logical foundation for subsequent exploration of the relationship between transfer coefficients and tourist satisfaction with the subway.

Based on the data from [Table 6](#) and the regression analysis logic discussed earlier, the proportion of satisfied subway passengers among subway-traveling tourists in each sample city is defined as tourist satisfaction with the subway (the dependent variable Y); the subway transfer coefficients of each city are used as the independent variable X to conduct a regression analysis, exploring the intrinsic relationship and evolution of both. To improve the explanatory depth of the satisfaction analysis, this paper constructs the following extended model:

$$S_i = \beta_0 + \beta_1 Transfer_i + \beta_2 Metro_i + \beta_3 Crowd_i + \beta_4 Service_i + \beta_5 CultureGuide_i + \mu_i \quad (4)$$

where S_i represents tourist satisfaction with the metro in city i ; $Transfer_i$ represents the transfer coefficient; $Metro_i$ represents metro operating mileage; $Crowd_i$ represents the degree of crowding; $Service_i$ represents the convenience of ticket purchasing, wayfinding, in-station services, and related services; represents the completeness of cultural tourism guide information in the metro system; and μ_i is the random error term. This model emphasizes that tourist satisfaction depends not only on the transfer coefficient, but also on whether the transfer process is clear, whether carriages are crowded, whether ticket purchasing is convenient, and whether stations provide clear tourism guide information. Therefore, satisfaction improvement should be promoted simultaneously from both transportation organization and tourism service perspectives.

The results of the regression analysis (as shown in [Table 2](#)) indicate that the multiple correlation coefficient (Multiple R) is 0.646, and the coefficient of determination (R Square) is 0.417, suggesting a moderate strength of correlation, and indicating that it is not a completely linear relationship, showing dynamic association characteristics overall. In the initial stages of subway construction, improving transfer coefficients can help tourists reduce time costs, flexibly choose routes, and enhance the utilization of subways in urban cultural tourism, as well as the tourist experience when accessing attractions; however, as the number of lines and stations increases, excessively adding transfer stations may increase the burden on tourists and weaken the positive impact of transfer coefficients on satisfaction, potentially leading to a negative correlation. This pattern confirms the regression relationship between the two, resonating with the earlier research logic and enhancing the coherence of the argument. Therefore, the influence of the transfer coefficient on tourist satisfaction has a “dual nature.” Moderate transfers help improve route accessibility and travel flexibility, while overly complex transfers may increase tourists’ cognitive burden and time costs. Especially for non-local tourists, route identification during transfers, walking distance within stations, clarity of language signage, and station guidance systems all affect their actual experience. Therefore, when serving tourism scenarios, urban rail transit should improve network connectivity while reducing transfer complexity.

Discussion

This study shows that there is a significant multidimensional relationship between urban rail transit and urban tourism. Rail transit is not merely a basic mobility carrier; rather, by optimizing the accessibility of cultural tourism nodes such as scenic areas, commercial districts, cultural venues, and historic districts, it profoundly influences urban tourism development from multiple dimensions, including travel behavior, accommodation choice, route planning, and tourism experience.

From the perspective of tourists’ travel behavior, the survey shows that the metro is the preferred mode of transportation for tourists in urban tourism. The main reasons are that it offers stable travel times, high cost performance, and clear routes, while also helping tourists avoid surface traffic congestion and meet their travel needs in unfamiliar cities. However, rail transit is not the only determining factor in tourists’ travel choices. Urban cultural tourism attractiveness, the spatial layout of scenic areas, and tourists’ personal characteristics all exert intervening effects. Therefore, rail transit is an important conditional variable affecting tourism behavior, rather than a decisive variable.

At the level of accommodation choice, tourists generally prefer accommodation near metro stations, and rail transit stations have become core spatial references in the layout of tourists’ cultural tourism activities. Tourists’ accommodation decisions take price, service, and transportation location into account. Accommodation near metro stations can effectively reduce travel time costs, improve the efficiency of visiting scenic areas, and promote the formation of urban cultural tourism consumption spaces, reflecting the significant tourism spatial spillover effect of rail transit.

From the perspective of cultural tourism resource utilization, rail transit can improve the accessibility and utilization rate of various urban cultural resources. The spatial matching degree between metro lines and cultural scenic areas, historic districts, and distinctive consumption areas directly affects the overall quality of urban tourism. Efficient route connections can form a coherent cultural tourism sightseeing system, whereas a disconnect between cultural tourism resources and the rail transit system may restrict the release of their tourism value.

The empirical regression results show that the scale of the rail transit network is highly correlated with tourists’ travel choices, while the transfer structure has a moderate correlation with tourist satisfaction. This confirms that the level of rail transit construction and network efficiency significantly affect the cultural tourism travel experience. At the same time, tourist satisfaction is also constrained by multiple factors, including carriage crowding, transfer convenience, signage and guidance, safety, and services.

In summary, empowering cultural tourism development through urban rail transit requires a shift from a single route-construction orientation to a comprehensive development orientation that coordinates network efficiency, service experience, and culture-tourism integration.

Conclusion

Based on the statistical analysis of questionnaire survey data, this paper explores the correlation and influence mechanism between urban rail transit and urban tourism, and draws the following conclusions.

First, the 21–40 age group shows significant advantages in tourism consumption and travel propensity, making it the main group in urban tourism. Age cannot independently affect tourists’ tourism behavior; rather, it works together

with factors such as income level, leisure time, and digital travel ability to influence tourists' transportation choices in urban tourism.

Second, the influence of income on tourism behavior is staged and complex. An overall increase in income can positively promote tourism willingness, but for some high-income groups, insufficient leisure time may lead to a negative correlation between tourism willingness and income. Travel preferences differ significantly among income groups. Middle-income groups are more attracted to the economy and convenience of the metro, while high-income groups prefer comfortable and personalized travel modes. Therefore, urban cultural tourism transportation services need to provide differentiated supply.

Third, tourists' metro-use experience directly affects their tourism transportation choices. Tourists who reside in cities with metro systems are more inclined to use the metro when traveling. Most tourists plan travel routes and choose accommodation locations near metro stations based on metro access. Rail transit deeply intervenes in tourists' travel and accommodation decisions and has become a core framework through which tourists perceive and organize the spatial pattern of urban tourism.

Fourth, the degree of improvement of the rail transit network is an important reference for tourists in choosing tourist destinations. Its cultural tourism value does not lie primarily in operating mileage, but in the degree of spatial coupling and adaptation with tourism resources such as scenic areas, cultural venues, commercial areas, and accommodation. Only efficient connection with resources can fully realize its supporting role in cultural tourism.

Fifth, based on the regression analysis of the sample cities, metro mileage and tourists' propensity to use the metro, as well as the transfer coefficient and tourism satisfaction, respectively show strong and moderate correlations. These results only reflect correlations among variables and cannot determine strict causal effects. In the future, long-term panel data and spatial econometric models can be used to conduct more in-depth research.

Sixth, rail transit can effectively improve the accessibility of urban cultural tourism resources, optimize the organization of cultural tourism routes, and enhance the efficiency of transforming cultural resources into tourism value.

In summary, rail transit is an important support for the high-quality development of urban culture and tourism, but it is not the only determining factor. This paper constructs a composite mechanism of "transport accessibility—tourism resource connectivity—tourist behavioral response—tourism experience improvement," comprehensively explaining the integrated role of rail transit in empowering culture-tourism integration, urban spatial organization, and the upgrading of tourism consumption.

Practical implications

Based on the above research conclusions, this paper proposes the following practical implications.

First, urban rail transit planning should strengthen coordination with the layout of tourism resources. When constructing or optimizing future rail transit lines, full consideration should be given to the connections among core scenic areas, historic and cultural districts, museums, urban landmarks, commercial consumption areas, and transportation hubs, so as to improve the coverage of tourism resources by rail transit.

Second, the service functions of key tourism stations should be optimized. For metro stations near scenic areas, cultural venues, and commercial districts, tourist guide maps, directional signs to scenic areas, walking-time reminders, multilingual signage, and introductions to urban culture can be added to reduce the route-identification costs of non-local tourists in unfamiliar cities.

Third, transfer convenience and riding comfort should be improved. The study shows that there is a moderate correlation between the transfer coefficient and tourist satisfaction, but overly complex transfers may weaken tourists' experience. Therefore, tourists' metro travel experience should be improved by optimizing in-station circulation, shortening transfer distances, improving transfer signage, and strengthening passenger-flow organization during peak periods.

Fourth, the integration of rail transit and cultural tourism products should be promoted. Cities can create cultural tourism themed routes around metro lines, such as historical and cultural routes, museum routes, night-tour consumption routes, and urban landmark routes, thereby transforming rail transit from a single travel tool into a platform for urban cultural display and tourism experience organization.

Fifth, attention should be paid to the differentiated needs of different tourist groups. For elderly tourists and tourists from cities without metro systems, ticket-purchasing guidance, route inquiry services, and manual consultation should be strengthened. For younger tourists, digital guidance, online transfer planning, and tourism recommendations along metro lines can be enhanced to improve service precision.

Limitations and outlook

Although this paper can provide certain insights for tourism transportation policy formulation, it still has the following limitations.

First, the number of sample cities is limited. This study selects ten Chinese cities with relatively high metro operating mileage as samples, which can reflect the basic characteristics of cities with relatively developed rail transit. However, its explanatory power for small and medium-sized cities, tourism-oriented cities, and cities in the early stage of rail transit development remains limited.

Second, the data in this paper mainly come from questionnaire surveys. Although the sample size is relatively large, the results may still be affected by respondents' subjective perceptions, recall bias, and individual preferences.

Third, the regression analysis in this paper is mainly based on cross-sectional data, which can reveal correlations

between rail transit indicators and tourist behavior, but remains insufficient for identifying causal relationships.

Fourth, due to limitations in data availability, this paper has not yet conducted refined spatial analysis of the spatial distribution of cultural resources, the actual distances between metro stations and cultural attractions, and tourists' real movement trajectories.

Future research can be further deepened in the following aspects. First, the scope of sample cities can be expanded to include cities of different sizes, different tourism types, and different stages of rail transit development for comparison. Second, multi-year panel data can be introduced to analyze changes in urban tourism flows and tourist behavior before and after the opening of rail transit lines. Third, POI data, mobile signaling data, metro smart-card data, and tourist trajectory data can be combined to conduct more refined spatial econometric research. Fourth, future studies can focus on analyzing the spatial coupling relationship between rail transit and cultural tourism resources, further revealing how rail transit influences urban cultural tourism experiences and cultural tourism consumption spaces.

In conclusion, there is a significant interactive relationship between urban rail transit and urban tourism. Rail transit not only improves tourists' travel efficiency, but also serves as an important support for the high-quality development of urban tourism by connecting tourism resources, reshaping tourism spaces, enhancing the accessibility of cultural resources, and optimizing the tourism experience. In the future, a more coordinated mechanism should be established among rail transit planning, tourism resource development, and urban cultural space governance, so as to promote a positive interaction between urban transportation construction and the integrated development of culture and tourism.

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"Knowing How to Chat" to "Driving Conversions": A Study on the Emotional Labor of Douyin E-commerce Livestreamers Under Platform Discipline

Mingxuan Yu ¹, Susu Zeng ^{2, *}

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Abstract: The emotional labor of apparel e-commerce livestreamers serves as an important entry point for understanding the labor logic of livestream e-commerce. Through in-depth interviews with 15 Douyin e-commerce livestreamers, this paper examines the process by which emotional labor transforms from "knowing how to chat" to "driving conversions" under platform discipline. The study finds that the emotional labor of livestreamers unfolds across four stages: intimate expression, outfit explanation and try-on demonstration, emotional mobilization and rhythm advancement, and after-sales appeasement and relationship maintenance, thereby forming a complete conversion mechanism. Through three interlocking mechanisms of data assessment, livestreaming systems, and team training, the platform screens and solidifies the livestreamers' emotional expressions into a set of calculable sales scripts. In this process, the workers' strategy of "pseudo-authenticity" constitutes a soft resistance to disciplinary power. Although it provides limited psychological compensation, it also imperceptibly reinforces their identification with platform norms, causing them to remain more deeply entrenched within the disciplinary order.

Keywords: E-commerce livestreamers; Emotional labor; Platform discipline; Livestream e-commerce

Introduction

In Douyin apparel livestreaming rooms, a seemingly paradoxical phenomenon warrants attention: livestreamers spend a significant amount of time engaging in "chatting"—such as sharing outfit ideas and expressing personal feelings—that does not directly promote sales, yet this significantly boosts product sales. From "knowing how to chat" to "driving conversions" this process is not a natural outpouring of the livestreamer's personal communication talent, but a quantitative reshaping of emotional communication mediated by platform technology. "Chatting" has thus evolved from a free form of interpersonal communication into emotional work that must achieve quantifiable results. Taking Douyin e-commerce livestreamers as the research subject and employing in-depth interviews, this paper examines how this transformation occurs and how the emotional experiences of livestreamers change during this process.

Literature Review

How does "chatting" become labor?

Existing studies have shown that interactions initiated by live-commerce streamers serve as an important means of relationship building. By constructing narrative-based scenarios, employing fictive-kinship forms of address, and providing continuous emotional feedback, streamers create a temporary community grounded in trust and intimacy in front of the screen ([Wongkitrungrueng & Assarut, 2020](#)). From the perspective of relational labor, such sustained communication also constitutes an important means through which streamers establish and maintain social relationships with their audiences ([Baym, 2015](#)).

In apparel livestreaming, these interactions also involve aesthetic advice and bodily display. Streamers not only provide information about products but also respond to viewers' needs in the role of fashion consultants. The visibility, real-time responsiveness, and shopping guidance afforded

¹ Tianjin University of Finance and Economics, Tianjin 300222, China; ² Guangxi Vocational Normal University, Nanning 530007, China.

* Corresponding author. Email: 20220021@gxvnu.edu.cn.

by livestreaming can enhance consumer engagement while reducing, to some extent, uncertainty regarding product quality and personal suitability ([Sun et al., 2019](#); [Lu & Chen, 2021](#)).

Existing research on conversational interaction in livestreaming has generally regarded it either as a natural manifestation of the streamer's personal charisma or as an inherently effective marketing instrument. Such interpretations, however, leave an important question unresolved. If conversational competence were merely an individual talent or an experiential skill, it would not need to be systematically managed, trained, and evaluated. In practice, however, streamers' conversational performances are increasingly subject to organizational management, professional training, and performance assessment.

In *The Managed Heart: Commercialization of Human Feeling*, Hochschild (1983) introduced the concept of emotional labor. Drawing on an empirical study of flight attendants, she demonstrated that the emotional expressions of service workers are not simply spontaneous manifestations of private feelings. Rather, they are performances conducted in accordance with feeling rules and display rules established by organizations.

Within apparel livestreaming, "chatting" involves not only the commodification of emotion but also the digital encoding of aesthetic labor. Through verbal description, streamers translate physical properties that are invisible or difficult to perceive through a screen—such as fabric texture, tailoring, silhouette, and drape—into intelligible aesthetic images. In doing so, they connect interpersonal communication with the production of commercial value. Research on aesthetic labor has similarly demonstrated that workers' appearance, voice, posture, and bodily style can be organized and mobilized as economically valuable labor resources ([Witz et al., 2003](#)).

The tension between workers' authentic feelings and institutional demands gives rise to surface acting and deep acting. The emotional-labor framework thus removes emotion from the exclusively private sphere and conceptualizes it as a labor product that can be systematically produced, managed, appropriated, and exploited. From this perspective, conversational interaction in livestreaming is no longer simply an expression of an individual's ability to speak persuasively. It is a form of emotional labor that is deliberately organized and managed.

Subsequent scholars have extended this model in two principal directions. Bolton and Boyd (2003) argued that workers do not invariably comply passively with organizational requirements. In some circumstances, they may regard emotional labor as a gift through which they bring pleasure or comfort to others. From a political-economic perspective, Brook (2009) criticized emotional-labor theory for concentrating excessively on managerial control while paying insufficient attention to exploitation, particularly the process through which capital converts the use value of emotion into exchange value. The former perspective foregrounds workers' subjective experiences in the performance

of emotional labor, whereas the latter reveals the structural incorporation of emotional capacities into processes of capital accumulation. Both perspectives inform the present study's analysis of how streamers' emotional labor is transformed into economic value.

How do data reshape "chatting"?

The preceding discussion directs attention to the feedback mechanisms through which emotional labor is organized. Hochschild's model of organizational management and Bolton and Boyd's gift model primarily examine how workers provide services to customers. They offer less detailed accounts, however, of how workers are continuously measured and evaluated by external forces, and how such evaluations subsequently reshape the labor process itself.

Livestreaming analytics dashboards display indicators such as viewer-entry rates, audience retention, interaction frequency, and conversion rates. Taken together, these metrics constitute an increasingly systematic framework for the quantitative evaluation of streamers' affective performances. Research has shown that digital measurement technologies not only track workers' observable behavior but also incorporate stress, emotional states, and perceived productivity into managerial processes, thereby making emotional labor itself monitorable and calculable ([Moore, 2018](#)). Through traffic allocation, recommendation ranking, and account classification, platform algorithms continuously identify and reward interaction patterns associated with higher conversion rates. Algorithmic control therefore reshapes both the behavioral patterns and working strategies of digital platform workers ([Kellogg et al., 2020](#); [Wood et al., 2019](#)).

More importantly, the post-stream review tools provided by platforms and livestreaming agencies can immediately decompose successful conversational performances into analytically manageable components, including product framing, emotional progression, pacing, objection handling, and key conversion points. Through this process, human speech and affect are increasingly subjected to coding, classification, and standardization. Foucault's concept of discipline provides a productive framework for understanding this process. Through hierarchical observation, normalizing judgment, and examination, disciplinary power exercises detailed control over individuals and transforms them into "docile bodies" ([Foucault, 1977](#)).

Studies of digital labor have demonstrated that algorithms can establish a form of control resembling panoptic surveillance by continuously monitoring the locations, movements, and working conditions of delivery workers and ride-hailing drivers ([Rosenblat & Stark, 2016](#); [Wood et al., 2019](#)). The data displays used in livestreaming operate according to a similar logic. Their disciplinary scope, however, extends beyond bodily movement to encompass deeper levels of emotional expression, verbal performance, and interpersonal communication.

More specifically, the analytics dashboard corresponds to hierarchical observation because it converts interactional performance into numerical indicators that can be continu-

ously tracked. The decomposition of successful scripts through post-stream review corresponds to normalizing judgment because it establishes particular conversational practices as standardized models. The promotion and elimination mechanisms associated with platform traffic pools correspond to examination because they classify, select, and allocate workers according to quantified performance. Together, these mechanisms constitute a comprehensive disciplinary process directed at the emotional and communicative expressions of streamers.

Nevertheless, an analysis based solely on discipline leaves a crucial issue unresolved. Disciplinary theory is particularly effective in explaining how power produces compliant subjects, but it is less capable of explaining why workers may voluntarily participate in their own discipline. In livestreaming practice, many streamers do not merely endure data-based evaluation. Instead, they actively study their analytics dashboards, learn the conversational scripts associated with highly successful streams, and enthusiastically pursue higher conversion rates.

In *Manufacturing Consent*, Burawoy (1979) provided an important explanation of workers' active participation in the labor process. He identified the workplace game of "making out," through which piece-rate wages, rankings, and competitive incentives construct workers as voluntary participants who actively pursue production targets rather than as individuals who are simply coerced into labor. Livestreaming dashboards create a comparable game-like environment. Constantly changing metrics, ranking lists, and the promotion and elimination mechanisms of platform traffic pools transform streamers into "players" who continuously strive to achieve higher performance indicators.

Discipline and the manufacture of consent are therefore not merely parallel mechanisms. From a disciplinary perspective, the analytics dashboard functions as a panoptic instrument of surveillance: streamers modify their behavior because they fear poor performance. Within the logic of the workplace game, however, the nature of this surveillance changes. Data no longer operate solely as an external source of judgment; they become an object of aspiration that streamers seek to master.

The streamer's orientation consequently shifts from "I am being evaluated by data" to "I must improve my data." The passive "docile body" is transformed into an active and enterprising self. Discipline is thereby internalized in a form that workers themselves come to desire. Streamers are not simply compelled to increase conversion rates; they aspire to become more effective at producing conversions. This transformation from an external gaze to a self-directed gaze constitutes one of the more subtle mechanisms of platform governance.

The preceding analysis demonstrates that data systems can convert emotional interaction into measurable and comparable forms. Nevertheless, the effects of such systems vary across product categories because different commodities possess different sensory characteristics and generate different levels of emotional involvement among consumers. It

is therefore necessary to consider why disciplinary practices directed at conversational interaction are particularly pronounced in apparel livestreaming.

Why apparel livestreaming?

The distinctive character of apparel livestreaming must be understood in relation to a fundamental sensory condition: clothing consumption depends heavily on tactile experience, whereas online shopping prevents consumers from directly accessing such experience. Fabric texture, softness, comfort against the skin, weight, and drape ordinarily need to be verified through touch and physical try-on. Consumers vary in their reliance on tactile information when evaluating products, and the absence of such information can increase the difficulty of assessing product quality and personal suitability (Peck & Childers, 2003). This sensory deficit brings the streamer's body to the forefront of the labor process.

Research on the body in communication studies—from Peters's philosophical reflections on the bodily limits of communication, to McLuhan's understanding of media as extensions of the human body, and to posthumanist examinations of the integration of bodies and technologies—has consistently demonstrated the importance of bodily presence in mediated communication (Peters, 1999; McLuhan, 1964; Hayles, 1999). In virtual shopping environments, consumers cannot physically touch commodities as they would in offline retail settings. The streamer's body consequently becomes particularly important because it encounters the product on behalf of the consumer and communicates aspects of its tactile qualities.

Through such practices as trying on garments, turning to display their fit from different angles, touching or stretching fabrics, and verbally describing material qualities, streamers provide a form of tactile compensation. Sensory experiences that cannot be directly accessed through the screen are translated into visual, auditory, and imaginable forms. The body, in this context, should not be understood as an enclosed biological entity but as an open system deeply integrated with media and technology (Hayles, 1999). In apparel livestreaming, the streamer's body provides a concrete manifestation of this body-technology system. Cameras, lighting, filters, and audio equipment extend and modify the digital representation of the streamer's body, while consumers' imagined relationships with their own bodies are simultaneously activated and guided through these technological arrangements.

Clothing also plays a distinctive role in the construction of consumer identity, which gives the imagined act of trying on garments a meaning that extends beyond functional product evaluation. Possessions are not limited to their practical use value; they may also operate as extensions of the self and as resources for identity expression (Belk, 1988). When a viewer asks, "Would this trench coat suit me?", the question is not limited to sizing or fit. The viewer is also imagining how they might look in the garment and what kind of person they might become by wearing it.

Communication between apparel streamers and viewers therefore provides a bridge for the projection of identity fantasies. Through the display of their own bodies and the verbal articulation of aesthetic styles, streamers enable consumers to imagine a possible future self. Clothing is not merely a commodity placed on the surface of the body; it is a cultural form closely connected to embodied practice and social identity (Entwistle, 2000). Emotional labor centered on identity construction thus engages with the potential transformation of the self rather than merely producing momentary sensory pleasure.

Within the specific environment of the livestreaming room, bodily display is intended not only to demonstrate the advantages of garments but also to present the body in accordance with established aesthetic standards. Research on digital content production has shown that platform workers are frequently required to balance commercial demands with the performance of authenticity. They produce an appearance of naturalness through carefully designed forms of everyday, informal, and personalized expression (Abidin, 2017; Duffy & Hund, 2019). From this perspective, even when platforms and agencies impose standardized requirements and fixed scripts, workers may still inject individualized features into otherwise routinized performances. This raises a further question: does this effort to produce “performed authenticity” weaken platform discipline, or does it ultimately reinforce disciplinary control?

When streamers derive satisfaction from making minor personalized adjustments within a standardized framework and consequently feel that they have preserved a degree of individuality, does this sense of autonomy make them more willing to remain within the standardized labor system? If so, performed authenticity may not constitute genuine resistance to discipline. Rather, it may represent another dimension of the manufacture of consent.

In this sense, performed authenticity functions as a safety valve within the disciplinary system rather than as an effective challenge to it. By preserving a limited degree of individualized expression within standardized performances, streamers may alleviate the sense of alienation produced by routinized labor. At the same time, however, this limited autonomy may strengthen their acceptance of the platform’s labor rules.

Conversational interaction in apparel livestreaming is therefore a composite form of labor. It encompasses aesthetic judgment, tactile substitution, and the mediation of identity imaginaries, while simultaneously involving verbal expression, bodily performance, and emotional influence. When platforms discipline this labor through conversion-centered metrics, what is decomposed and standardized is not limited to conversational technique. The process also encompasses streamers’ subtle aesthetic judgments, their ability to interpret embodied differences, and their capacity to guide consumers’ imagined identities. These forms of labor are highly contextual and resistant to complete standardization, even as platforms continually attempt to render them

measurable, reproducible, and subject to performance evaluation.

Research Methods and Sample Selection

This paper employs in-depth interviews, combining snowball sampling and purposive sampling, to select 15 e-commerce livestreamers at different stages of their career development and across various apparel sub-sectors for interviews (See Table 1). Regarding age, the interviewed livestreamers range from 21 to 40 years old, which is highly consistent with the primary age demographic of current apparel e-commerce consumers. Among them are 12 females and 3 males, reflecting the industry’s gender structure while accommodating male representation in sectors like streetwear and business menswear. Their livestreaming experience ranges from 2 months (resigned) to 5 years, which helps study the impact of platform rules on livestreamers at different career stages. In terms of category coverage, the sample encompasses 15 sub-sectors, including Korean-style young ladies’ wear, plus-size womenswear, high-end silk and cashmere, maternity wear, sports and outdoor wear, and traditional ancient-style (Hanfu) clothing.

Specific Manifestations of the Emotional Labor of e-commerce livestreamers Livestreamers narrow the distance with the audience through intimate expression

In apparel livestreaming rooms, intimate expression is usually the starting point of emotional labor. Livestreamers use everyday terms of address to soften the commercial tone of the sales pitch scenario, laying an emotional foundation for subsequent product sales. They typically adopt daily, colloquial, and relatable expressions to maintain interactive stickiness with the audience, transforming the livestreaming room from a one-way promotional scene into an interactive space imbued with a sense of companionship. A plus-size womenswear livestreamer with two years of experience (P2) remarked: “I don’t start by saying how much this piece of clothing costs. Instead, I first ask if they’ve eaten today and if there are any petite sisters here.” This expression involves a deep performance strategy: the livestreamer establishes intimacy through a non-sales posture and uses this to achieve sales targets.

However, intimate expression is not synonymous with fake performance. An ancient-style apparel livestreamer with a year and a half of experience (P10) emphasized the importance of “understanding”: “The audience doesn’t come in to take a class; they come to find someone who understands them. If you say this length is friendly to petite girls, they know you are on their side.” It is evident that intimate expression is driven by both emotional investment and the platform’s conversion logic. When the strategy of “understanding you” is proven by data to have a traffic-drawing effect, communication that originally carried a sense of gift-

Table 1 | Basic Information of Interviewed Douyin e-commerce livestreamers

No.	Age	Gender	Livestreaming Experience	Main Apparel Category	Interview Method
P1	23	Female	6 months	Korean-style womenswear (Young ladies)	Online voice interview
P2	28	Female	2 years	Plus-size womenswear	Offline face-to-face interview
P3	35	Female	3 years	High-end silk and cashmere	WeChat video interview
P4	25	Male	1 year	Streetwear menswear	Online voice interview
P5	30	Female	4 years	Maternity wear	Telephone interview
P6	22	Female	3 months	Fast fashion influencer styles	Online text interview
P7	40	Female	5 years	Middle-aged and elderly womenswear	Offline wholesale market stall visit
P8	27	Male	8 months	Sports and outdoor, yoga wear	Online voice interview
P9	32	Female	2.5 years	Designer brands	WeChat voice call
P10	24	Female	1.5 years	Ancient-style (Hanfu) clothing	Online video interview
P11	29	Female	1 year	Underwear, loungewear	Telephone interview
P12	26	Female	2 years	Commuter, workplace formal wear	Offline interview
P13	33	Male	3 years	Business menswear, shirts and trousers	WeChat text interview
P14	21	Female	2 months (resigned)	Shoes and bag pairing	Telephone follow-up
P15	31	Female	4 years	/	Online voice interview

giving becomes solidified into standardized opening scripts. This intimate expression, acting as a core emotional labor strategy, seemingly neutralizes sales traces but actually lays the foundation for subsequent sales conversion and emotional monetization by constructing emotional stickiness and trust.

Outfit explanation and try-on demonstration: The critical path to building consumer trust

The trust mechanism in apparel livestreaming relies heavily on the livestreamer's embodied demonstration of the goods. Embodied behaviors in e-commerce livestreaming, such as personal try-ons and experience sharing, can enhance the persuasiveness of the livestreamer's recommendations. Since audiences cannot try clothes online, livestreamers must advance "seeing the clothes" to "believing it suits me" through on-body demonstrations, turning around, close-up shots, and styling instructions. Therefore, livestreamers must not only announce the size, price, and material, but also translate the silhouette, length, drape, thickness, and applicable scenarios into a wearing effect that the audience can visualize. A Korean-style womenswear livestreamer with 6 months of experience (P1) pointed out: "You can't just say the bust is 96 cm; you have to say that for sisters weighing 110 to 140 jin, this will tuck in the armpit fat nicely when worn. You also can't just say it's cotton; you must say it doesn't prickle against the skin and can also be worn in the summer." This type of explanation translates abstract data into concrete bodily experiences, addressing consumers' concerns regarding sizing, color, and scenario suitability while establishing a baseline of trust. A high-end silk and cashmere livestreamer with 3 years of experience (P3) further emphasized the importance of bodily movements: "Silk tends to look dull on camera; only when worn and moving around can its flowing elegance be shown amid the changing light." Clearly, the livestreamer's body is not merely a clothing display tool, but a mediatized sensory intermediary. Sensory compensation mechanisms constructed

through bodily movements such as trying on, turning, and close-ups provide audiences with a sensory experience of a "virtual-try-on".

In the mediatized environment, the livestreamer's body is woven into a 'body-technology' system, becoming the consumer's 'extended sensorium'. Through embodied performances like trying on and turning around, unreachable material properties are transformed into quantifiable visual symbols, thus completing cross-screen sensory compensation.

Emotional mobilization and rhythm advancement: On-site drivers for immediate ordering

Once intimate relationships and trust are preliminarily established, livestreamers must push consumers to place orders through emotional mobilization and rhythm advancement. Apparel consumption is somewhat impulsive, and whether an audience purchases often depends on whether the livestreamer can create a sense of urgency and drive decision-making within a limited time. Livestreamers typically push audiences from a state of observation to a state of action by increasing their speaking speed, emphasizing inventory limits, setting countdowns, and calling out specific viewers to respond. For example, brand e-commerce livestreamers undergo various scripting and sales technique training from the moment they are hired; from unified terms of address to templated processes like "counting down three numbers, put up the link," their labor process increasingly resembles fast-paced, mechanized assembly line production. This rhythmic advancement places continuous demands on the livestreamer's emotions. Even during long livestreams where interaction decreases, livestreamers must maintain an excited, enthusiastic, and stable mode of expression to prevent the atmosphere from dropping and traffic from leaking. The platform's assessment of duration, follower growth, interaction, and transactions closely links emotional

mobilization to traffic pressure, turning emotions into a production resource that sustains the livestream's momentum. Platforms categorize livestreamers into different tiers based on metrics like annual streaming duration, follower count, follower growth trends, the purchase ratio of followers, livestream data trends, and the average number of video likes, comments, favorites, and shares. To retain audience traffic and avoid a drop in their room's ranking, livestreamers generally need to maintain interaction and drive the consumption rhythm in a highly tense state. Thus, immediate ordering in apparel e-commerce livestreams is constantly driven to completion under the combined forces of the livestreamer's continuous emotional mobilization, rhythm control, and platform data pressure.

However, the conversion goal of emotional labor does not end with the on-the-spot transaction. For livestreamers, what is truly valuable is not a one-time order, but a continuous consumption connection. A foreign trade original single apparel livestreamer with four years of experience (P15) stated: "A one-off deal won't last long. No matter how hard I push for the order today, if the customer receives the goods and is unsatisfied, he won't come back next time." Therefore, immediate transactions are not the end of emotional labor; after-sales appeasement and relationship maintenance present entirely new challenges for livestreamers.

After-sales appeasement and relationship maintenance: The continuation of conversion from one-time transactions to continuous connections

Because apparel products are characterized by high return and exchange rates, a livestreamer's emotional labor often extends into the after-sales phase. At this point, after-sales service is not merely technical problem-solving, but rather secondary maintenance of the trust relationship through emotional appeasement. Unlike the "continuation" mode of ambiguous relationships reliant on "push and pull" strategies seen in entertainment/showcase livestreams, the communication and interaction between e-commerce livestreamers and their audiences are based more on the professional role of a "wardrobe consultant". The core of maintaining an intimate distance relies on practical trust, not ambiguous attraction. A commuter formal wear livestreamer with two years of experience (P12) shared her after-sales handling experience, typically opting for a gentler approach: "Baozi (Honey/Darling), this color is closer to its true shade under natural light. Why don't you try it again tomorrow morning, and if you still don't like it, I'll process a return for you." This strategy effectively maintains long-term relationships between merchants and consumers by balancing problem-solving with emotional care.

It is clear that emotional labor does not stop when a transaction is completed; instead, it transitions into relationship maintenance, forming a backbone for future consumption relationships.

Platform Discipline: The Institutional Shaping of Emotional Labor

Data assessment: The traffic orientation of emotional expression

Data assessment is the core mechanism by which emotional labor is continuously reinforced. The Douyin platform provides metrics such as view counts, retention times, interaction rates, follower conversion rates, and transaction volumes, supplying livestreamers with data-based evidence to adjust their forms of address, speaking speed, and display methods. When a certain expression brings higher interaction or sales, it is repeatedly used and precipitates into stable scripts. Therefore, while the emotional expressions and scripts of livestreamers appear to be on-the-spot improvisations, they are essentially the shaping and disciplining of emotional expression by the platform's data logic. However, not all livestreamers can adapt to this mode of emotional discipline. Shoes and bags livestreamer who resigned after only two months (P14) confessed: "I couldn't stand that fake, hyped-up atmosphere. Whenever I saw the cold numbers, I was actually very anxious inside, but I still had to pretend to be enjoying afternoon tea with the sisters in a high-end mall. They (the operations team) were always saying 'you need to shout like this,' 'you need to laugh like this,' and I felt like that just wasn't me." In a follow-up, this livestreamer further stated: "It's not that I resisted the data; it's just that I couldn't do it right no matter how I tried. Others could close deals by shouting their lines, but it had no effect when I shouted. The operations team said I wasn't loose enough." The departure of this livestreamer demonstrates that data assessment has a screening function: those who adapt to the metrics are kept, while those who do not are marginalized. This structural pressure causes most livestreamers to attribute problems to their own mismatch with the platform, rather than to the platform's exploitation itself. This perfectly echoes the micro-manifestations of capital logic pointed out by Brook. A middle-aged and elderly womenswear livestreamer with 5 years of experience (P7) gradually began to see the data dashboard as a game: "At first, I didn't dare look at the data. Later, I would analyze why retention time increased by three seconds today, which sentence caused it, and which style made the comment section most active—it's like playing a video game." In her eyes, data is no longer just a cold monitor, but has transformed into an object of desire through the 'making-out game' mechanism. The livestreamer's self-actualization is narrowed down to numerical growth. The internalization of self-gaze shifts the discipline from external coercion to the subject's self-drive. The "consent" tailored by the platform for the workers makes them unknowingly view the platform's goals as their own while pursuing data, invisibly contributing free labor to the platform.

Furthermore, the disciplinary effect of data assessment is also intuitively reflected in the alienation of the emotional 'gift'. When data dashboards repeatedly verify the traffic-drawing effect of a certain sentence, it is extracted from the

context of a gift and fixed as a standard configuration in the opening script. The livestreamer no longer says this sentence because she "wants to help the viewer," but because "saying it yields good data". When the gift is overlaid by performance, the qualitative nature of emotional labor undergoes an imperceptible yet irreversible change.

Livestreaming systems: The time discipline of emotional investment

In addition to data assessments, livestreaming systems also impose time discipline on livestreamers through factors like duration and frequency. Platform capital uses flexible working hours as a cover, but in reality, it covertly extends working hours, even expropriating personal rest time without compensation. Consequently, livestreamers often "voluntarily" extend their streaming hours, and continue to manage fan groups, process after-sales issues, and reply to private messages after going offline.

A Hanfu livestreamer with a year and a half of experience (P10) described the physical and mental exhaustion after a stream: "After going offline, I feel physically hollowed out. Sometimes someone @s me in the fan group; I see it but don't want to reply, yet a few hours later I feel guilty and end up replying anyway." This 'hollowed out' exhaustion and the 'guilt' felt when not replying indicate that the livestreamer's emotional labor has broken through work boundaries, extending uncompensated into personal rest time.

A foreign trade apparel livestreamer with four years of experience (P15) explicitly pointed out: "It's not that the agency forces you to stream more; it's that you don't dare stream less. If you stream one hour less, the traffic is gone. It's not that I'm hardworking; it's that I'm afraid." This reveals the intrinsic connection between livestreaming rules and algorithmic mechanisms. It shows that time discipline does not manifest as mandatory administrative orders, but is covertly transformed into the algorithm's traffic allocation mechanism. The compulsory nature of the rules is masked by the objectivity of the algorithm, prompting workers to rationalize their self-imposed pressure as an active, rational choice. Instead, it is internalized as the livestreamer's self-requirement through algorithmic allocation and competitive pressure.

In such an institutional environment, the emotional labor borne by e-commerce livestreamers has actually exceeded simple on-camera expression, transforming into a highly dense form of labor shaped jointly by duration requirements, appearance frequency, and emotional control. Therefore, the livestreaming system's discipline of livestreamers not only rearranges their work schedules but also continuously compresses their emotional recovery space, gradually making emotional labor a daily practice hovering perpetually on the edge of burnout.

Team training: The tension between standardization of interactive presentation and "pseudo-authenticity"

Team training outside of the livestream further drives the standardization of emotional labor. After joining an agency, livestreamers usually must undergo training in scripts, actions, camera presence, pacing, and after-sales procedures. Dai Yingjie and Lü Zijian describe this phenomenon as "assembly line production," meaning brand livestreamers must accept uniform script and process training from the day they onboard, with their work processes broken down into replicable, assessable, and standardized segments. Many interviewees indicated that while standardized training improved sales data, it weakened their autonomy of expression. An underwear and loungewear livestreamer with 1 year of experience (P11) said: "At first I thought it was effective, the data really did go up, but the more I learned, the faker I felt. The words you say aren't what you truly want to say, but you have to say them anyway." To resist the alienating experience brought about by emotional standardization, some livestreamers have developed "pseudo-authenticity" expressive strategies. For example, a designer brand livestreamer with 2.5 years of experience (P9), when broadcasting the agency's unified order-forcing script "inventory is low, hurry up and order," intentionally embeds personal life experiences: "These are pieces I kept for myself; it looks great in photos when dining out nicely yesterday," seeking to gain a limited sense of control—"these words are still mine"—amidst mechanical labor.

This personalized presentation maneuvered within standardized scripts is by no means a true victory for the worker's subjectivity. As a defensive strategy, "pseudo-authenticity" provides the subject with faint psychological compensation, but on a macro level, it acts as a "safety valve" for the disciplinary system. It cleverly dissolves the workers' resistance to assembly-line operations. The stealth and effectiveness of platform discipline lie precisely here: it does not seek to entirely obliterate the subjectivity of digital laborers, but rather draws safe boundaries for them that can be commercially co-opted, allowing workers, under the illusion of "limited autonomy," to bond capital logic with self-identity, ultimately making them even more compliant within the platform's normative order.

Conclusion

The emotional labor of Douyin apparel e-commerce livestreamers has become the outcome of interactions among platform discipline, corporate shaping, and consumers. The shift from "knowing how to chat" to "driving conversions" marks a change in the nature of labor within e-commerce livestreaming rooms. Chatting is no longer an open interpersonal exchange, but is alienated into a data-driven capability that can increase retention, interaction, and transactions. e-commerce livestreamers construct an emotional labor chain through intimate expression, try-on

demonstrations, emotional mobilization, and after-sales appeasement. Within this chain, the platform filters effective emotional expressions through data assessment, compresses emotional recovery time via livestreaming systems, and standardizes scripts, actions, and aesthetic judgments through team training, thereby forming a closed loop of discipline over e-commerce livestreamers.

Livestreamers retain partial subjectivity; they embed their personal experiences, tone, and style into the platform's standardized scripts to form an expressive strategy of "pseudo-authenticity". While this strategy offers them limited self-affirmation, it also deeply entrenches them in the platform's labor order, obscuring the platform's regulatory control and labor control. It is thus clear that platform discipline does not simply suppress the subjectivity of workers, but manufactures "consent" through covert means like data games, time pressure, and limited autonomy, turning them into uncompensated laborers and victims of the platform society.

The logical evolution of e-commerce livestreamers from 'being able to chat' to 'being able to convert' reveals the comprehensive rationalization of human relational society by technology, as well as the invisible control and discipline platforms exert over digital workers in a platform society. Future industry governance, while pursuing efficiency metrics, should further focus on the emotional depletion, time boundaries, and diversity of aesthetic labor among digital workers, reserving offline spaces for emotional repair to prevent the exhaustion of aesthetic labor.

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Guest Editor: Di Lu

Professor School of Journalism & Communication, Peking University, Beijing, China; Director, Center for Surrounding Communication Studies, Peking University

This section serves as a strategic cooperation platform with the Center for Surrounding Communication Studies, Peking University. It is dedicated to advancing the systematic development of China's original "Surrounding Communication Theory" and fostering global dialogue. The theory was first proposed by Professor Di LU in 2013 and has since been recognized as one of the "Four Major Indigenous Theories in Journalism and Communication Studies in China" and one of the "Top Ten Original Theories in Chinese Philosophy and Social Sciences." It provides an innovative analytical framework for understanding geopolitical information flows and cross-cultural communication mechanisms. It seeks to:

- Paradigm innovation and empirical studies in surrounding communication
 - Comparative analyses of regional communication ecosystems
 - Digital media's evolving role in geopolitical discourse
 - Mechanisms of cross-border cultural diffusion
 - Policy evaluation in transnational communication governance
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**Thematic Section:
Frontier Research in Intellectual
Property Law**

Guest Editor: Yanmin Quan

Professor, School of Law, Xi'an Jiaotong University; Council Member, Intellectual Property Law Research Committee of China Law Society; Council Member, China Law Society on Science and Technology Law

This section invites scholarly inquiry into the frontiers of Intellectual Property (IP) law, entertainment law, and the legal governance of traditional culture. It emphasizes the evolutionary trajectory of legal systems amidst the dual pressures of globalization and digital transformation. We welcome research that bridges theoretical legal frameworks with practical applications in industrial innovation and social governance. Key themes include, but are not limited to:

- IP protection and emergent legal challenges in the digital economy.
- Legal mechanisms for IP licensing, financing, and fostering industrial innovation.
- The platform economy, Generative AI (AIGC), and associated legal liabilities.
- Regulatory strategies and countermeasures against malicious IP litigation in cyberspace.

Submission Guidelines

JGTSS accepts the following manuscript types (all word counts include references and notes):

Research Articles (4,000–8,000 words): Original empirical or theoretical studies presenting novel findings and rigorous conceptual arguments.

Review Articles (4,000–8,000 words): Comprehensive and critical evaluations of major academic debates, research traditions, or emerging thematic directions.

Case Studies (4,000–6,000 words): In-depth analyses of specific projects, communities, or cultural practices with broader scholarly and theoretical implications.

Book Reviews (1,500–3,000 words): Analytical critiques of recently published monographs relevant to the journal's scope.

Note: Only original, unpublished works are considered. Translations of previously published material will not be accepted.

Peer review process

JGTSS adheres to a double-anonymized peer review model to ensure the highest standards of academic integrity. Each submission undergoes an initial internal screening by the editorial office to evaluate its alignment with the journal's scope and adherence to formatting requirements. Manuscripts that pass this preliminary stage are subsequently assigned to a minimum of two independent subject-matter experts for rigorous external evaluation.

Open access policy

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Submission logistics

Format & Channel: Authors are required to prepare manuscripts in Microsoft Word (.doc/.docx) format. All submissions must be managed through the journal's Electronic Submission Portal.

Compliance: Before initiating a submission, authors must ensure their manuscript strictly complies with the latest Author Guidelines.

Rolling Basis: The journal maintains a continuous submission cycle, accepting manuscripts year-round without fixed deadlines for general issues.

Article processing charges (APC)

To support the costs of open-access publishing, JGTSS levies a one-time Article Processing Charge (APC) of USD 80 for each manuscript successfully accepted for publication.

Journal metadata & Contact

Submission Portal: <https://jandoopress.com/journal/jgtss>

Editorial Office: For all inquiries regarding the submission process or editorial decisions, please direct correspondence to contact@press.jandoo.ac.

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