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Integrating industrial engineering tools and behavioral modeling for optimizing operational efficiency in nature-based tourism services

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Abstract
This study proposes a hybrid approach integrating behavioral modeling (PLS-SEM) and engineering diagnostics (Value Stream Mapping, Time Study, and Spaghetti Diagram) to evaluate and optimize service performance in nature-based tourism. Using survey data from 280 visitors to two West Java destinations, we test the effects of ergonomic design, service quality, technology integration, and environmental perception on operational efficiency, tourist satisfaction, and revisit intention. The structural model indicates that ergonomic design and environmental perception significantly enhance operational efficiency (ERG→OPE β = 0.404; ENV→OPE β = 0.552), which in turn strongly predicts satisfaction (OPE→SAT β = 0.944) and revisit intention (OPE→RI β = 0.619). The model shows substantial explanatory power (R^2: OPE = 0.621; SAT = 0.891; RI = 0.383). Field diagnostics corroborate these findings: non-value-added time accounts for 38% of the end-to-end process, with notable delays at ticketing (+2.3 minutes vs standard) and route overlaps in high-density zones. Results suggest that environmental and ergonomic factors outperform technology and formal service attributes in driving outcomes within nature-based contexts. Theoretically, the study extends the S-O-R framework by positioning operational efficiency as a meso-level mediator linking physical stimuli to behavioral responses and bridging perception-based modeling with systems diagnostics. It provides actionable guidance for lean service redesign, wayfinding, and spatial reconfiguration to improve operational performance and visitor experience.

Keywords:
Operational Efficiency;
PLS-SEM;
Tourism Services;
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INTRODUCTION

Nature-based tourism (NBT) has increasingly been recognized as a vehicle for sustainability, cultural heritage preservation, and environmental education, offering tangible economic and ecological benefits to local communities and governments [1][2]. However, as visitor volumes grow, many destinations encounter stubborn operational frictions, fragmented customer flows, inflexible spatial layouts, and limited adoption of digital tools, particularly during peak periods [1][3]. Such shortcomings are frequently amplified by legacy infrastructure and the absence of ergonomically conceived service systems [4][5].

Concurrently, advances in data-driven tourism point to the promise of innovative technologies and digital ergonomics to improve the visitor experience and operational performance [6][7]. Nevertheless, structured instruments for service diagnostics and spatial (re)design remain underused in NBT settings. Contemporary scholarship on innovative tourism systems argues for combining behaviourally informed design with system-level analysis to deliver adaptive, user-centric services [8]. The present study is theoretically anchored in the Stimulus–Organism–Response (S-O-R) framework and Service System Design Theory, wherein physical stimuli, layout, environmental cues, and service interactions shape internal evaluations (e.g., satisfaction) that, in turn, drive behavioural outcomes such as loyalty and revisit intention [9][10].

Although prior research has investigated individual behavioural constructs, service quality, ergonomic design, and environmental perception, few studies have integrated these with industrial-engineering diagnostics such as Value Stream Mapping (VSM), Time Study, and Spaghetti Diagram analysis [11]. To address this gap, we advance a hybrid analytical framework that links behavioural modelling via Partial Least Squares Structural Equation Modeling (PLS-SEM) with engineering-based process mapping and performance benchmarking.

The contribution of this work lies in a multidimensional evaluation model that captures both perceived and observable service inefficiencies, thereby providing a more comprehensive understanding of how internal design, environmental cues, and system flow influence satisfaction and loyalty. This integration enables managers to transition from reactive firefighting to proactive service design—an imperative in destinations where physical accessibility and environmental immersion are integral to the experience [12][13].

Accordingly, the study pursues four objectives: (1) to analyse how ergonomic design, service quality, technology integration, and environmental perception influence operational efficiency; (2) to assess the mediating role of operational efficiency in shaping tourist satisfaction and revisit intention; (3) to diagnose inefficiencies using engineering tools; and (4) to integrate perception-based and observation-based evidence into a unified decision-making model. Theoretically, we modify and extend service-system evaluation by incorporating behavioural constructs alongside engineering metrics. In practice, we provide actionable guidance on spatial layout redesign, queue management, and lean service optimisation in NBT contexts.

METHOD

Research Design

This study employs a quantitative explanatory research design integrating behavioral modeling with engineering-based diagnostics. It investigates the causal effects of ergonomic layout, service quality, technology use, and environmental perception on operational efficiency, tourist satisfaction, and revisit intention. Grounded in service system design theory, the research conceptualizes nature-based destinations as multi-touchpoint service systems. Behavioural data were analyzed using Partial Least Squares Structural Equation Modelling (PLS-SEM) [14], while process inefficiencies were identified using Value Stream Mapping, Time Study, and Layout Analysis [15]. This mixed-method approach enables triangulation, providing comprehensive insights that link perceptual data with objective operational diagnostics.

Object and Subject of the Study

This study examines the integrated service system across two well-known nature-based destinations in West Java, Kawah Putih Ciwidey and Gunung Tangkuban Perahu. The unit of analysis is the end-to-end visitor journey encompassing pre-arrival, on-site flow, and exit processes within each destination's service ecosystem. The research subjects comprise domestic tourists aged 17 or older who visited either site within the past 12 months. Using purposive sampling, we obtained 280 valid responses through a structured questionnaire. Field observations were conducted to capture real-time service flow, spatial layout, and operational performance, complementing the survey evidence and documented using engineering-based tools and techniques.

Theoretical Justification of Multi-Site Selection

Selecting two nature-based destinations in West Java, Kawah Putih Ciwidey and Tangkuban Perahu, follows a purposive multi-site design intended to maximize contextual variation (terrain, access patterns, visitor flows, and vendor–visitor touchpoints) while holding the destination class constant. Purposeful variation in contexts strengthens external validity by testing whether patterns observed in one setting replicate in another, enabling both effect- and sign-generalization across sites [16].

From an operations and service-design perspective, field-based research emphasizes that performance outcomes and traveler experiences are contingent on local process architectures and service scripts; hence, comparative, cross-site designs provide more credible generalization than a single-site study [17]. In hospitality and tourism, recent methodological reviews and domain studies support the use of multiple or comparative cases to build transferable process insights, especially for lean-service and flow-management interventions, thereby improving analytic generalization beyond a single attraction [18]. In addition, because this study employs purposive sampling of domestic tourists, we address representativeness by examining within- and between-group cohesiveness; recent work shows that non-probability samples can still yield externally valid inferences [19].

Variables and Measurement Instrument

Seven latent variables were measured using reflective indicators adapted from validated sources. Ergonomic Design and Environmental Perception items were derived from previous studies emphasizing spatial usability, sensory quality, and eco-alignment in tourism environments [20][21]. Service Quality was measured using the SERVQUAL model, focusing on the responsiveness, reliability, and assurance dimensions relevant to tourism settings [22]. Technology Integration captured digital tool usage, automation, and perceived usefulness, as informed by recent studies on innovative tourism services and digital ergonomics [23], and reinforced by [12], who emphasized the growing role of digital interaction platforms in enhancing tourism service quality and visitor personalization.

Operational Efficiency indicators refer to perceived flow smoothness, queue reduction, and layout adaptability following established tourism performance metrics [24]. Tourist Satisfaction was operationalized through overall experience evaluations, alignment with expectations, and affective outcomes [13], while Revisit Intention focused on intention to return, likelihood to recommend, and continued preference [25]. All measurement items used a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) and were validated through an expert panel review to ensure construct clarity and contextual relevance.

Observational & Engineering Data Collection

To complement survey-based perceptions, this study employed observational methods rooted in industrial engineering to assess operational inefficiencies at Kawah Putih Ciwidey and Gunung Tangkuban Perahu. Tools included Value Stream Mapping (VSM), Time Study, and Spaghetti Diagrams to map visitor flow, measure delays, and detect spatial constraints. Observations were conducted during peak periods, focusing on queue lengths, process durations, and routing patterns.

This approach accords with recent tourism operations scholarship that integrates engineering diagnostics to evaluate real-time service constraints and infrastructure readiness [26]. Evidence from community-based tourism shows that VSM effectively exposes waste along the service chain and guides flow redesign for lean interventions [27]. In parallel, advances in hybrid modelling recommend coupling PLS-SEM with selected machine-learning algorithms to strengthen predictive assessment; in our design, engineering traces provide process-level triangulation and inform model specification [28].

Triangulation and Integration

This study employed a triangulation strategy by integrating perception-based modeling (PLS-SEM) with engineering-based diagnostics to enhance the validity of the findings. Questionnaire data on ergonomic design, service quality, and technology use were statistically analyzed, while observations using VSM, Time Study, and Spaghetti Diagrams identified service inefficiencies. The alignment between subjective insights and objective field data strengthened the credibility of the results, supporting evidence-based recommendations aligned with system engineering principles to improve service delivery in nature-based tourism.

Data Analysis Procedure

The study employed a sequential, dual-track analytic strategy integrating perception modelling with operations diagnostics. First, the behavioural dataset (n = 280) was estimated in SmartPLS 4.0, where the measurement model was screened for indicator reliability and convergent validity (AVE and CR) and for discriminant validity using the HTMT criterion; the structural model was then assessed via path coefficients, effect sizes, and R^2, with significance obtained through bootstrapping [29]. Second, engineering evidence was generated by mapping the end-to-end visitor stream using Value Stream Mapping, timing activities with a standard Time Study, and evaluating circulation through Layout/Spaghetti analysis to identify queues, handoffs, and non-value-added movements [30]. Finally, outputs from both tracks were triangulated, aligning convergent patterns and probing discrepancies at specific service nodes, to yield a consolidated interpretation of system performance. As illustrated in Figure 1, the study followed an integrated methodological sequence that combined survey-based data collection and on-site process observation, proceeded through a dual analytical pathway consisting of PLS-SEM and engineering-based diagnostic tools, and concluded with triangulation to generate a consolidated interpretation of the results.

RESULTS AND DISCUSSION

Respondent Profile

Table 1 summarises the demographic and behavioural characteristics of 280 visitors to Kawah Putih Ciwidey and Gunung Tangkuban Perahu. The sample is broadly gender-balanced (male 53.57%; female 46.43%). Age concentrates among adults 31–45 (42.86%), followed by 18–30 (35.71%) and a smaller segment above 45 (21.43%).

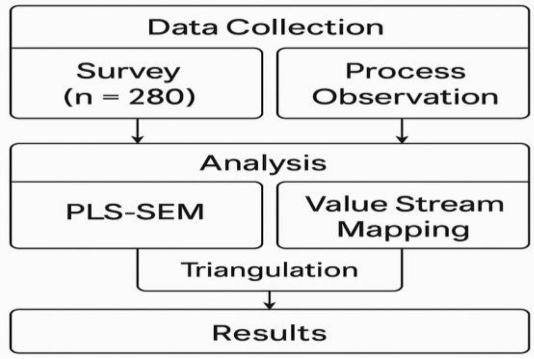

Figure 1. Methodological Framework (flow/diagram)

Most respondents are repeat visitors travelling more than once per year (64.29% versus 35.71% once per year), indicating accumulated familiarity with site logistics and seasonal patterns. Consistent with this behavioural profile, technology familiarity is generally high (71.43%), with a smaller group reporting low familiarity (28.57%). These attributes provide context for our perceptual modelling and engineering diagnostics, and they support segment-specific recommendations, e.g., e-ticketing and timed entry for digitally ready visitors, and a clear, legible wayfinding system to aid less familiar segments during peak periods.

External Model Assessment

Table 2 presents the evaluation of the reflective measurement model for seven latent constructs: ERG, SQ, TECH, ENV, OPE, SAT, and RI. All indicator loadings exceed 0.70, with TECH indicators above 0.93, indicating strong indicator reliability. Cronbach's Alpha and Composite Reliability values surpass 0.867 and 0.904, respectively, confirming internal consistency. AVE values for all constructs exceed 0.50, validating convergent validity—most notably OPE (0.895) and TECH (0.887). These results confirm that the measurement model is reliable and valid, supporting its use in subsequent structural model analysis using PLS-SEM

Table 1. Attributes of Review Respondents

Chars.	Dimension	Cat	(N)	(%)
Gender	Demo	Male	150	53.57
	Demo	Female	130	46.43
Age	Demo	18-30	100	35.71
	Demo	31-45	120	42.86
	Demo	>45	60	21.43
Visit Frequency	Behavioral	Once per year	100	35.71
	Behavioral	More than once per year	180	64.29
Technology Familiarity	Behavioral	Low familiarity	80	28.57
	Behavioral	High familiarity	200	71.43

Table 2. Analyses of the External Model

Construct / Item	Loadings	Alpha	CR	AVE
Ergonomic Design (ERG)		0.939	0.954	0.805
ERG1	0.920			
ERG2	0.924			
ERG3	0.920			
ERG4	0.886			
ERG5	0.831			
Service Quality (SQ)		0.867	0.904	0.653
SQ1	0.822			
SQ2	0.749			
SQ3	0.825			
SQ4	0.840			
SQ5	0.801			
Technology Integration (TECH)		0.957	0.969	0.887
TECH1	0.941			
TECH2	0.954			

TECH3	0.941			
TECH4	0.931			
Environmental Perception (ENV)		0.888	0.922	0.746
ENV1	0.826			
ENV2	0.856			
ENV3	0.882			
ENV4	0.890			
Operational Efficiency (OPE)		0.942	0.963	0.895
OPE1	0.947			
OPE2	0.944			
OPE3	0.947			
Tourist Satisfaction (SAT)		0.939	0.957	0.847
SAT1	0.947			
SAT2	0.928			
SAT3	0.937			
SAT4	0.867			
Revisit Intention (RI)		0.881	0.926	0.808
RI1	0.920			
RI2	0.917			
RI3	0.858			

External Model Assessment

Table 3 presents the Fornell-Larcker criterion results, which assess discriminant validity in the PLS-SEM model. Each construct's AVE square root exceeds its inter-construct correlations, indicating adequate discriminant validity. For example, ENV (0.864) and OPE (0.946) exceed their respective correlations, with OPE achieving its highest correlation with SAT (0.944). While these values meet the criterion, the closeness suggests supplementary validation using the HTMT ratio may be warranted to confirm construct distinctiveness.

Table 4 summarises the structural model evaluation using key PLS-SEM criteria: effect size (f^2), coefficient of determination (R^2), and predictive relevance (Q^2). Operational Efficiency ($R^2 = 0.621$) and Tourist Satisfaction ($R^2 = 0.891$) show strong explanatory power, while Revisit Intention ($R^2 = 0.383$) is moderate. All Q^2 values exceed 0.00, confirming predictive relevance. Effect sizes indicate moderate effects for Environmental Perception (0.129) and Ergonomic Design (0.095), while Service Quality and Technology Integration show negligible effects. The model demonstrates robust explanatory strength and predictive validity, particularly for satisfaction-related outcomes.

Figure 2 displays the structural model for seven latent constructs. Operational Efficiency (OPE) serves as the core mediator, most strongly influenced by Environmental Perception (3.840) and Ergonomic Design (3.781). It significantly predicts Tourist Satisfaction (8.431) and Revisit Intention (12.408).

Table 3. Result of Discriminant Validity

Variable	EENV	ERG	OPE	RI	SQ	TECH	SAT
ENV	0.864						
ERG	0.608	0.897					
OPE	0.605	0.596	0.946				
RI	0.605	0.604	0.619	0.899			
SQ	0.823	0.805	0.580	0.728	0.808		
TECH	0.843	0.530	0.464	0.514	0.801	0.942	
SAT	0.629	0.612	0.944	0.644	0.597	0.482	0.920

Table 4. Effect Size (f^2), Determination (R^2), and Predictive Relevance (Q^2)

Variable	f^2			R^2	Q^2
	OPE	RI	SAT		
ENV	0.129				
ERG	0.095				
OPE		0.621	8.184	0.459	0.403
RI				0.383	0.302
SQ	0.002				
TECH	0.010				
SAT				0.891	0.745

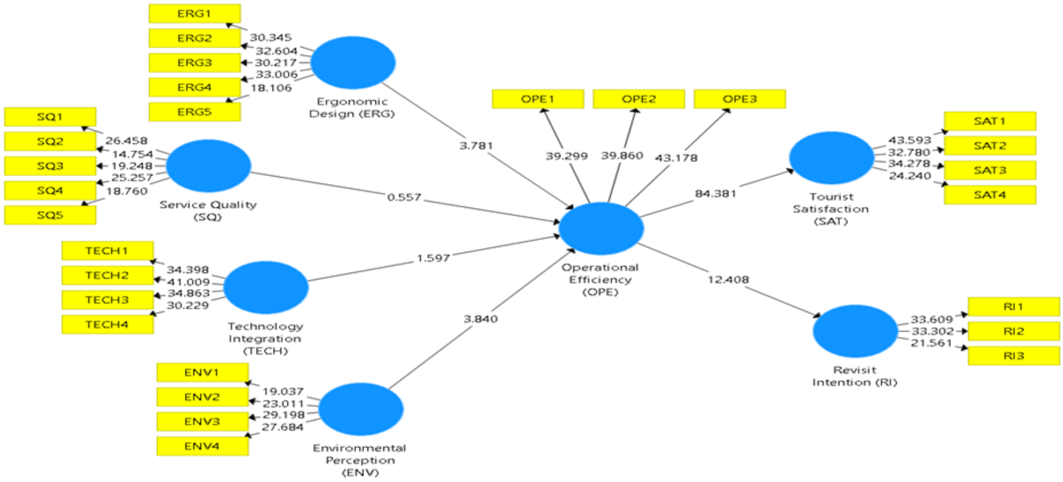

Figure 2. Structural Model (PLS-SEM)

Tourist Satisfaction also has a significant positive effect on Revisit Intention (t = 3.360), supporting a sequential pathway in which ergonomic design and environmental perception enhance operational efficiency, which in turn increases satisfaction and strengthens revisit intention. All indicators show outer loadings greater than 0.70, supporting reliability; the paths are significant ($p < 0.05$, bootstrapped). Consistent with S-O-R logic, the model explains how environmental and ergonomic levers translate into efficiency, satisfaction, and loyalty in NBT.

Table 5 presents bootstrapping results, including path coefficients (β), t-values, and p-values at a 5% significance level. Ergonomic Design (ERG) significantly influences Operational Efficiency (OPE), Tourist Satisfaction (SAT), and Revisit Intention (RI), underscoring its critical role. Environmental Perception (ENV) also shows strong positive effects on these outcomes. Conversely, Technology Integration (TECH) and Service Quality (SQ) exhibit no significant influence. OPE strongly predicts SAT (β = 0.944) and RI (β = 0.619), underscoring its mediating and predictive relevance. These findings validate several hypotheses, highlighting the dominance of environmental and ergonomic factors over technology or perceived service quality.

Table 6 reports specific indirect effects, assessing Operational Efficiency (OPE) as a mediator between exogenous constructs (ERG, SQ, TECH, ENV) and outcomes (SAT, RI). Significant mediation occurs for ERG and ENV, indicating that their influence on satisfaction and revisit intention operates through OPE. For example, ENV → OPE → SAT (β = 0.521, p = 0.000) is strongly significant. In contrast, indirect effects for SQ and TECH are non-significant. These results highlight OPE's mediating role in translating design and environmental factors into behavioural outcomes, while SQ and TECH may require reconsideration or alternate mediators for further exploration.

Table 5. Bootstrapping Effect Results

Construct	Original Sample (O)	T Statistics (|O/STDEV|)	P Values
Ergonomic Design (ERG)_ -> Operational Efficiency (OPE)	0.404	3.781	0.000*
Ergonomic Design (ERG)_ -> Revisit Intention (RI)	0.250	3.974	0.000*
Ergonomic Design (ERG)_ -> Tourist Satisfaction (SAT)	0.381	3.743	0.000*
Service Quality (SQ) -> Operational Efficiency (OPE)	-0.076	0.557	0.578
Service Quality (SQ) -> Revisit Intention (RI)	-0.047	0.561	0.575
Service Quality (SQ) -> Tourist Satisfaction (SAT)	-0.072	0.554	0.580
Technology Integration (TECH) -> Operational Efficiency (OPE)	-0.154	1.597	0.111
Technology Integration (TECH) -> Revisit Intention (RI)	-0.096	1.548	0.122
Technology Integration (TECH) -> Tourist Satisfaction (SAT)	-0.146	1.592	0.112
Environmental Perception (ENV) -> Operational Efficiency (OPE)	0.552	3.840	0.000*
Environmental Perception (ENV) -> Revisit Intention (RI)	0.342	3.741	0.000*
Environmental Perception (ENV) -> Tourist Satisfaction (SAT)	0.521	3.808	0.000*
Operational Efficiency (OPE) -> Revisit Intention (RI)	0.619	12.408	0.000*
Operational Efficiency (OPE) -> Tourist Satisfaction (SAT)	0.944	84.381	0.000*

* means significant at 5%

Table 6. Specific indirect effects

Construct	Original Sample (O)	T Statistics (|O/STDEV|)	P Values
Ergonomic Design (ERG)_ -> Operational Efficiency (OPE) -> Revisit Intention (RI)	0.250	3.974	0.000*
Ergonomic Design (ERG)_ -> Operational Efficiency (OPE) -> Tourist Satisfaction (SAT)	0.381	3.743	0.000*
Service Quality (SQ) -> Operational Efficiency (OPE) -> Revisit Intention (RI)	-0.047	0.561	0.575
Service Quality (SQ) -> Operational Efficiency (OPE) -> Tourist Satisfaction (SAT)	-0.072	0.554	0.580
Technology Integration (TECH) -> Operational Efficiency (OPE) -> Revisit Intention (RI)	-0.096	1.548	0.122
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Environmental Perception (ENV) -> Operational Efficiency (OPE) -> Tourist Satisfaction (SAT)	0.521	3.808	0.000*

* means significant at 5%

Engineering Tools Results

Value Stream Mapping (VSM)

The Value Stream Mapping (VSM) Table 7 analysis revealed a total lead time of 73 minutes, with only 45 minutes classified as value-added and 28 minutes (38%) as non-value-added (NVA) activities. Inefficiencies were linked to manual ticketing, unclear navigation, and scattered rest areas. Recommended improvements include self-service ticketing, colour-coded signage, and centralized rest zones. The projected future-state VSM suggests a 25% reduction in total time and a 40% decrease in NVA, enhancing operational efficiency and visitor experience.

Time Study Output

Time study analysis Table 8 revealed notable gaps between observed and standard service durations. Ticketing showed the most significant deviation (+2.3 minutes), followed by information services (+2.2 minutes) and restroom access (+2.5 minutes). Additional minor inefficiencies were identified in the entry validation and exit processes. These discrepancies point to time-based bottlenecks, particularly in manually operated areas. The findings suggest the need for streamlined procedures, optimized staffing, and supportive technologies to enhance processing speed and improve overall service efficiency in high-volume tourism settings.

Table 7. Observation Table for Industrial Engineering Tools

Activity	Process Time (min)	Wait time (min)	Operator	Waste or Bottleneck Noted
Arrival & Parking	3	5	Security	Delay due to limited parking
Ticket Purchase	5.8	7	Cashier	Manual transaction & long queue
Entry Checkpoint	2.5	4	Gate Officer	Duplicate verification
Information Counter	6.2	3	Guide	Lengthy inquiry time
Rest Area Use	7.5	2	Attendant	Poorly distributed rest zones
Exit Process	3	1	Exit Staff	Low congestion

Table 8. Time Study Output

Activity	Observed time (min)	Standard Time (min)	Gap (min)
Ticketing	5.8	3.5	+2.3
Information Service	6.2	4.0	+2.2
Restroom + Access	7.5	5.0	+2.5
Entry Validation	2.5	2.0	+0.5
Exit Process	3.0	2.0	+1.0

Layout Analysis (Spaghetti Diagram)

Figure 3 maps visitor trajectories at Gunung Tangkuban Perahu and Kawah Putih Ciwidey. Routes were collected by shadowing visitors along predefined segments during peak hours (weekends/holidays, 09:00–15:00); entry/exit times at nodes (entrance, ticketing, information, rest area, attractions, exit) were timestamped, and paths were digitised onto a georeferenced site plan (50 routes per site). The plot exposes non-linear paths, cross-flows, and a recurrent overlap node where streams from ticketing, information, and rest areas intersect, creating congestion and backtracking—especially for elderly visitors. High-density zones occur around food stalls and service counters. These patterns indicate layout-driven delays consistent with the Time Study and VSM (e.g., NVA segments at transitions). Recommended interventions include one-way pedestrian loops, relocating the information counter closer to ticketing, centralized rest zones, and colour-coded line-of-sight signage to reduce crossing, shorten walking distances, and stabilize flow.

Figure 4 presents the future-state value stream map aligning service capacity to takt (480 operating minutes/day; 1,000 visitors/day ⇒ takt ≈ 28.8 s per visitor). Timed-entry functions as the pacemaker preceding arrival, with the process sequence covering online pre-booking, e-ticket scan, merged security lanes, shuttle dispatch on a one-way loop, trail experience with enhanced wayfinding, centralised rest nodes, and an exit feedback kiosk. Data boxes specify each step's target PT, CT, WIP, and NVA. Key countermeasures remove bottlenecks: e-ticketing eliminates manual queues; merged lanes and visual cues reduce CT by ~35%; the one-way loop cuts crossings and dwell; wayfinding and timed slots smooth arrivals; and centralised nodes reduce backtracking. Performance goals are an end-to-end lead time of 35–45% and NVA of 38% to ≤18%, synchronizing throughput to takt. The map operationalises the mediated pathway via Operational Efficiency to Satisfaction and Revisit Intention.

Discussion

The cross-site design enhances the credibility of our inferences. Despite contrasts in terrain, circulation logic, demand rhythms, and digital readiness, the exact mechanism materialised at both destinations: Operational Efficiency (OPE) emerged as the central mediating construct linking Environmental Perception (ENV) and Ergonomic Design (ERG) to the study outcomes. As shown in Figure 2, ENV had the strongest positive effect on OPE (β = 0.552), followed by ERG (β = 0.404). In turn, OPE significantly influenced Tourist Satisfaction (SAT) (β = 0.944) and Revisit Intention (RI) (β = 0.619), with the corresponding t-values in Table 5 confirming statistical significance at $p < 0.05$. In effect, legible environments and ergonomically coherent layouts do more than please the eye; they unclog flow, lower frictions, and elevate satisfaction and loyalty.

The indirect paths in Table 6 corroborate the mediation. For example, ERG→OPE→RI (β = 0.250, t = 3.974, p = 0.000) and ERG→OPE→SAT (β = 0.381, t = 3.743, p = 0.000) indicate that design works through efficiency rather than bypassing it. Mechanistically, ergonomic alignment reduces handoffs and ambiguity, while favourable environmental cues dampen cognitive and affective strain. Together, these conditions compress perceived and actual effort, reduce detours, improve routing clarity, and shorten wait times, producing higher service evaluations and stronger intentions to return.

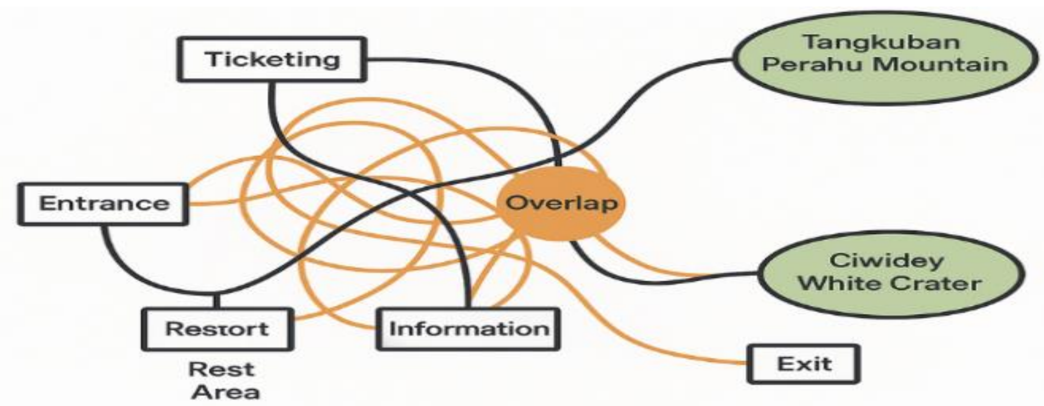

Figure 3. Spaghetti Diagram

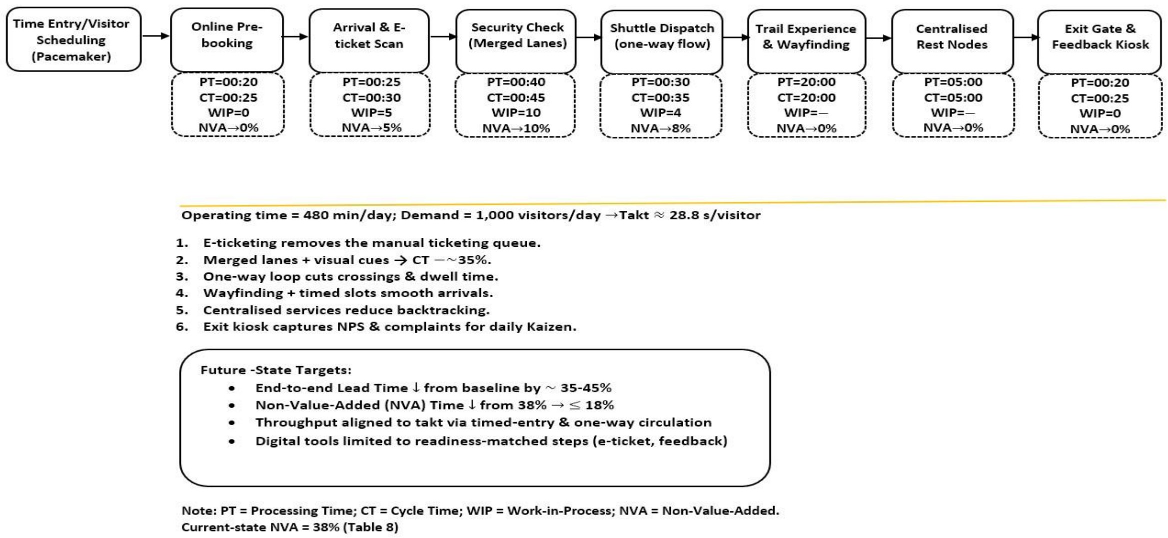

Figure 4. Future-State Value Stream Map and Target Metrics.

Engineering diagnostics substantiate the perceptual model. Table 8 records 38% non-value-added (NVA) time across the end-to-end journey, with pronounced losses at ticketing (+2.3 minutes versus standard) and during transitions. Spaghetti diagrams reveal cross-traffic and congestion at service nodes, aligning with OPE as a systemic rather than piecemeal construct. The convergence between PLS-SEM and VSM/Time/Spaghetti implies that what visitors label "efficient" corresponds to measurable reductions in cycle time and routing complexity. Building on this evidence, the future-state VSM (Figure 4) bundles countermeasures—timed entry, merged security lanes with clear visual cues, one-way circulation, and centralised rest nodes—into an actionable design for flow stabilisation.

A contextual result indicates that Technology Integration (TECH) and Service Quality (SQ) are not significant for SAT and RI. This diverges from findings in technology-forward or urban settings [1][23] and is plausible for three reasons. First, digital readiness in our sample is uneven; non-intuitive tools yield limited marginal utility versus spatial fixes. Second, visitors favour authenticity and unobtrusive facilitation in nature-based contexts over additional digital layers, consistent with rural/eco observations [12]. Third, the diagnostics locate physical bottlenecks (queue geometry, node placement) as primary constraints; without addressing these, incremental digital features are unlikely to move system-level metrics.

These results extend prior work linking ergonomic coherence to customer outcomes through spatial efficiency and user comfort [20], and they reinforce the role of environmental quality in shaping affective evaluations and loyalty [7]. Theoretically, we (i) elaborate the S-O-R perspective by positioning OPE as a meso-level mediator that operationalises how stimuli convert into responses across sites, and (ii) advance a hybrid behaviour–operations lens that binds perception-based modelling to engineering diagnostics. Practically, the priority is clear: in nature-based tourism, tangible spatial and environmental levers outperform digital add-ons, suggesting initial investments in lean flow redesign, one-way circulation, centralised rest zones, and legible wayfinding, with technology deployed as a complement rather than a substitute for sound service geometry [26].

These findings are consistent with previous studies showing that visitor satisfaction and loyalty are strongly influenced by experience quality, environmental conditions, and the smoothness of service encounters [1][13]. The significant roles of ergonomic design and environmental perception also support earlier research emphasizing the importance of comfort, usability, and the service environment in shaping tourism experiences [7][20]. However, the non-significant effects of Technology Integration and Service Quality differ from findings reported in more technology-oriented settings, where digital features and formal service attributes often play a stronger role [23][26]. This difference suggests that, in nature-based tourism, visitors may place greater importance on environmental immersion, clear layout, and reduced physical effort than on additional digital features. Thus, the present study highlights that the relative importance of service-system elements depends on context, with physical and environmental design becoming more decisive in nature-based destinations.

CONCLUSION

This study examined how service design elements, ergonomic design, service quality, technology integration, and environmental perception shape operational efficiency, tourist satisfaction, and revisit intention in nature-based tourism. The research uses a hybrid design that combines PLS-SEM with industrial engineering diagnostics (Value Stream Mapping, Time Study, and Layout Analysis) to provide an integrated view of perceived and observed system performance. Results show that ergonomic design and environmental perception are the primary levers improving operational efficiency, elevating satisfaction, and encouraging return visits. By contrast, service quality and technology integration did not exhibit direct effects in this context, a pattern consistent with destinations where authentic, physical experiences precede formalized service scripts or digital augmentation. Engineering evidence corroborates the model, showing that value-added time accounts for 38% of the end-to-end journey, with significant losses at ticketing and transitional nodes; additionally, spaghetti mapping reveals congestion linked to suboptimal facility placement. The findings call for prioritizing ergonomic upgrades, rigorous environmental stewardship, and selective, readiness-matched digital tools. Adopting lean service principles, such as one-way circulation, centralized rest zones, and legible wayfinding, can deliver measurable cycle-time gains while preserving the experiential quality of the space.

Limitations and future research. This study focuses on two sites in West Java and employs a cross-sectional, self-reported design collected during peak periods; thus, generalizability and temporal dynamics may be limited. Future work should adopt multi-site, longitudinal designs and replication logic to bolster external validity and theory extension. Future research could also undertake before-and-after or experimental evaluations of redesign strategies derived from VSM and time-based diagnostics, while incorporating lean service metrics, such as value-added share and cycle-time gaps, as additional outcome indicators. In parallel, a hybrid modelling agenda that triangulates perception-based estimation with system-level evidence, potentially including sensor-based flow telemetry, would strengthen causal inference and explanatory completeness in complex tourism settings. Finally, comparing NBT with urban or cultural tourism and testing alternative mediators (e.g., perceived value, crowding, affect) can further refine the behaviour–operations alignment advanced here.

REFERENCES

[1] N. M. Papadopoulou, M. A. Ribeiro, and G. Prayag, “Psychological Determinants of Tourist Satisfaction and Destination Loyalty: The Influence of Perceived Overcrowding and Overtourism,” *J. Travel Res.*, vol. 62, no. 3, pp. 644–662, 2022, doi: 10.1177/00472875221089049.

[2] B. Budianto, Z. O. Feri, Q. Nurlaila, H. Sitorus, and T. H. Suryatman, “Quality System as a Mediating Variable of the Relationship Between Lean Manufacturing and Operational Performance in the Food Industry,” *SINERGI*, vol. 27, no. 2, p. 201-210, 2023, doi: 10.22441/sinergi. 2023.2.008.

[3] F. Wang and C. López, “Does Communicating Safety Matter?” *Ann. Tour. Res.*, vol. 80, p. 102805, 2020, doi: 10.1016/j.annals.2019.102805.

[4] Y. E. Wella, O. Okfalisa, F. Insani, F. Saeed, and A. R. C. Hussin, “Service Quality Dealer Identification: The Optimization of K-Means Clustering,” *SINERGI*, vol. 27, no. 3, p. 433-442, 2023, doi: 10.22441/sinergi. 2023.3.014.

[5] W. Knollenberg, N. G. McGehee, R. R. Perdue, and K. L. Andereck, “We are All in This Together: Understanding How Tourism Advocates Build Relationships Across the Tourism Industry,” *J. Travel Res.*, vol. 60, no. 2, pp. 235–250, 2020, doi: 10.1177/0047287520906216.

[6] S. Amalia, I. Deborah, and I. N. Yulita, “Comparative Analysis of Classification Algorithm: Random Forest, SPAARC, and MLP for Airlines Customer Satisfaction,” *SINERGI*, vol. 26, no. 2, p. 213-222, 2022, doi: 10.22441/sinergi. 2022.2.010.

[7] A. M. El-Sherbeeny *et al.*, “How Is Job Performance Affected by Ergonomics in the Tourism and Hospitality Industry? Mediating Roles of Work Engagement and Talent Retention,” *Sustainability*, vol. 15, no. 20, p. 14947, 2023, doi: 10.3390/su152014947.

[8] I. K. W. Lai, J. W. C. Wong, and M. Hitchcock, “A Study of How LGBTQ Tourists’ Perceptions of Residents’ Feelings About Them Affect Their Revisit Intentions: An Emotional Solidarity Perspective,” *J. Sustain. Tour*, vol. 32, no. 1, pp. 223–244, 2022, doi: 10.1080/09669582.2022. 2130339.

[9] A. Kirilenko, S. Ma, S. O. Stepchenkova, L. Su, and T. F. Waddell, “Detecting Early Signs of Overtourism: Bringing Together Indicators of Tourism Development With Data Fusion,” *J. Travel Res.*, vol. 62, no. 2,

pp. 382–398, 2021, doi: 10.1177/00472875211064635.

[10] I. D. G. A. D. Putra and I. M. Adhika, "The Traditional Village as a Part of a Cultural Landscape: The Development of Cultural Agriculture Tourism in Catur, Bali," *SINERGI*, vol. 28, no. 1, pp. 43–54, 2024, doi: 10.22441/sinergi. 2024.1.005.

[11] S. Park, J. Lee, and J. L. Nicolau, "Understanding the Dynamics of the Quality of Airline Service Attributes: Satisfiers and Dissatisfiers," *Tour. Manag.*, vol. 81, p. 104163, 2020, doi: 10.1016/j.tourman.2020. 104163.

[12] M. Seočanac, "PLS-SEM: A hidden gem in tourism research methodology," *Hotel Tour. Manag.*, vol. 12, no. 1, pp. 115–131, 2024, doi: 10.5937/menhottur2400005s.

[13] F. Bagheri, M. Guerreiro, P. Pinto, and Z. Ghaderi, "From Tourist Experience to Satisfaction and Loyalty: Exploring the Role of a Sense of Well-Being," *J. Travel Res.*, vol. 63, no. 8, pp. 1989–2004, 2023, doi: 10.1177/00472875231201509.

[14] J. F. Hair, M. Sarstedt, C. M. Ringle, P. N. Sharma, and B. D. Liengaard, "Going beyond the untold facts in PLS–SEM and moving forward," *Eur. J. Mark.*, vol. 58, no. 13, pp. 81–106, 2024, doi: 10.1108/EJM-08-2023-0645.

[15] D. Hussain and M. C. Figueiredo, "Improving the time-based performance of the preparatory stage in textile manufacturing process with value stream mapping," *Bus. Process Manag. J.*, vol. 29, no. 3, pp. 801–837, Jan. 2023, doi: 10.1108/BPMJ-08-2022-0366.

[16] N. Egami and E. Hartman, "Elements of External Validity: Framework, Design, and Analysis," *Am. Polit. Sci. Rev.*, vol. 117, no. 3, pp. 1070–1088, 2023, doi: 10.1017/S0003055422000880.

[17] Y. Gao, M. Li, and S. Sun, "Field experiments in operations management," *J. Oper. Manag.*, vol. 69, no. 4, pp. 676–701, Jun. 2023, doi: https://doi.org/10.1002/joom. 1240.

[18] V. Perdomo-Verdecia, M. Sacristán-Díaz, and P. Garrido-Vega, "Lean management in hotels: Where we are and where we might go," *Int. J. Hosp. Manag.*, vol. 104, Art. no. 103250, 2022, doi: 10.1016/j.ijhm.2022. 103250.

[19] S. Babashahi, P. Hansen, and R. Peeters, "External validity of multi-criteria preference data obtained from non-random sampling: measuring cohesiveness within and between groups," *Ann. Oper. Res.*, vol. 325, no. 2, pp. 939–949, 2023, doi: 10.1007/s10479-022-05026-2.

[20] L. L. Bove and S. Benoit, "Restrict, Clean and Protect: Signaling Consumer Safety During the Pandemic and Beyond," *J. Serv. Manag.*, vol. 31, no. 6, pp. 1185–1202, 2020, doi: 10.1108/josm-05-2020-0157.

[21] Y. Liang, M. Lu, Z. M. Shen, and R. Tang, "Data Center Network Design for Internet-Related Services and Cloud Computing," *Prod. Oper. Manag.*, vol. 30, no. 7, pp. 2077–2101, 2021, doi: 10.1111/poms. 13355.

[22] Z. Shi and H. Shang, "A Review on Quality of Service and SERVQUAL Model BT - HCI in Business, Government and Organizations," in *HCI in Business, Government and Organizations: 7th International Conference, HCIBGO 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings 22*, F. F.-H. No and K. Siau, Eds., Cham: Springer International Publishing, 2020, pp. 188–204. doi: 10.1007/978-3-030-50341-3_15.

[23] W. Batat and W. Hammedi, "The Extended Reality Technology (ERT) Framework for Designing Customer and Service Experiences in Phygital Settings: A Service Research Agenda," *J. Serv. Manag.*, vol. 34, no. 1, pp. 10–33, 2022, doi: 10.1108/josm-08-2022-0289.

[24] Y. Sun, P. Lin, and J. Higham, "Managing Tourism Emissions Through Optimizing the Tourism Demand Mix: Concept and Analysis," *Tour. Manag.*, vol. 81, p. 104161, 2020, doi: 10.1016/j.tourman.2020.104161.

[25] S. Wang, A. Berbekova, M. Uysal, and J. Wang, "Emotional Solidarity and Co-Creation of Experience as Determinants of Environmentally Responsible Behavior: A Stimulus-Organism-Response Theory Perspective," *J. Travel Res.*, vol. 63, no. 1, pp. 115–135, 2022, doi: 10.1177/00472875221146786.

[26] A. T. Rosário and J. C. Dias, "Exploring the Landscape of Smart Tourism: A Systematic Bibliometric Review of the Literature of the Internet of Things," *Adm. Sci.*, vol. 14, no. 2, 2024, doi: 10.3390/admsci14020022.

[27] W. Tatiyanantakul and K. Chindaprasert, "Integrating Lean Management Into Community-Based Tourism: Enhancing Efficiency in Tourism Supply Chains Through Value Stream Mapping Concept," *Humanit. Arts Soc. Sci. Stud.*, vol. 24, no. 2, pp. 277–291, 2024, doi:

10.69598/hasss.24.2.263703.
[28] N. F. Richter and A. A. Tudoran, “Elevating theoretical insight and predictive accuracy in business research: Combining PLS-SEM and selected machine learning algorithms,” *J. Bus. Res.*, vol. 173, no. December 2023, p. 114453, 2024, doi: 10.1016/j.jbusres.2023.114453.
[29] J. F. Hair Jr., G. T. M. Hult, C. M. Ringle, M. Sarstedt, N. P. Danks, S. Ray. Cham, "Review of Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R: A Workbook," In *Springer*, 2021, doi: 10.1080/10705511.2022.2108813.
[30] L. Fontoura *et al.*, “Real-time energy flow mapping: A VSM-based proposal for energy efficiency,” *J. Clean. Prod.*, vol. 419, p. 137871, 2023, doi.org/10.1016/j.jclepro. 2023.137871.