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Enhancing Civic Engagement Through Spatial Design: A Nudge Theory Approach to Lightscape Interventions and Cultural Heritage in Urban Environments

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Abstract

This study examines how spatial design, particularly lightscape interventions, operates as a behavioral nudge associated with collaborative participation intention in urban environments. Drawing on nudge theory, place attachment, and cultural heritage literature, we analyze data from a questionnaire survey of 720 urban residents across major metropolitan regions in Japan using structural equation modeling (SEM). The results indicate that urban development and cultural heritage assets are positively associated with lightscape interventions, which in turn show a strong positive relationship with collaborative participation intention. While urban development exhibits both direct and indirect relationships with participation intention, the influence of cultural heritage assets operates primarily through lightscape interventions as a mediating mechanism. These findings suggest that cultural heritage alone does not automatically stimulate civic participation; rather, its social value is activated when heritage resources are translated into meaningful spatial and visual experiences. Lightscape interventions thus serve as an effective non-coercive mechanism linking spatial and cultural resources to civic engagement intentions. This research offers valuable insights for urban planners and policymakers seeking design-based, non-coercive strategies to enhance citizens' place attachment and willingness to contribute to community activities.

Keywords: nudge theory; spatial design; lightscape interventions; structural equation modeling; cultural heritage; urban development; place identity; civic participation intention

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1. Introduction

The challenge of fostering civic engagement and collaborative participation in modern urban environments has become increasingly complex as cities face rapid technological change, demographic shifts, and social fragmentation [1]. Traditional public policy approaches to encouraging community participation often rely on formal legislation, economic incentives, or public education—mechanisms that can be resource-intensive, rigid, and occasionally meet with public resistance or apathy [2,3]. In response, urban researchers and designers have begun exploring alternative, non-coercive framework based on behavioral insights, particularly the application of Nudge Theory to spatial design [4,5].

Nudge Theory, popularized by Thaler and Sunstein [3], posits that subtle modifications to the choice architecture of physical and social environments can predictably alter human

choices without forbidding any options or significantly changing economic incentives. In spatial contexts, nudges offer promising tools for encouraging community involvement by leveraging automatic cognitive responses and affective connections to place [5]. While behavioral nudges have gained traction in health policy and green mobility, their application to urban lighting and spatial design—specifically regarding how night illumination functions as an environmental nudge—remains underexplored in empirical research. Recent studies confirm that spatial nudges can effectively support pro-environmental and social behaviors across varied settings [6–8], yet there is a critical need to investigate how lighting design operates within specific local contexts.

To address this literature gap, this study investigates how lightscape interventions—the strategic design and nighttime illumination of urban public spaces—serve as environmental nudging associated with citizens' collaborative participation intentions. Specifically, we examine the mediating mechanism of lightscape interventions in translating the value of physical urban development and cultural heritage assets into community engagement.

Japan provides an exceptional empirical setting for testing this framework. Japanese cities face pressing urban challenges, including rapid demographic aging, shrinking local populations, and the urgent necessity to sustain community vitality through citizen-led initiatives and local community engagement. Furthermore, Japan features a unique interplay between deeply rooted cultural heritage assets and modern urban infrastructure, where historical preservation and technological innovation frequently intersect. Clarifying how spatial design can activate civic intentions within this context is both timely and internationally relevant for urban heritage management.

This study makes three main contributions: (1) it offers empirical evidence demonstrating how spatial lighting nudges are positively associated with civic participation intentions; (2) it identifies the mediating mechanisms through which environmental design activates latent cultural and urban resources; and (3) it provides actionable guidance for urban planners seeking cost-effective, non-coercive spatial strategies to strengthen civic engagement in historical and modern urban contexts.

2. Literature Review

2.1. Nudge Theory and Urban Design

The application of behavioral insights to urban planning represents a major shift in understanding how physical environments shape civic behavior. Nudge theory recognizes that human decision-making relies heavily on automatic cognitive processes (System 1 thinking) that respond directly to spatial cues, visual aesthetics, and sensory inputs [9]. Rather than relying on top–down regulations or costly public information campaigns, spatial nudging modifies choice architecture so that desirable community behaviors become more intuitive, accessible, and appealing [1,10].

Compared to conventional planning models that assume fully rational citizens, spatial nudges account for psychological biases, place attachment, and social norm perception [11,12]. While urban nudging has been applied to physical activity (e.g., interactive staircases) and waste sorting [10,13], its systematic application to built lighting environments remains nascent. Critical urban scholars emphasize that spatial nudges must maintain high ethical standards, ensuring transparency and preserving individual autonomy rather than manipulating public behavior [12,14].

Furthermore, recent research underlines the role of cultural identity in shaping nudge efficacy. Hasanzadeh and Haghkhah [15] observed that cultural identity significantly mediates behavioral nudge responsiveness, indicating that effective spatial nudges must harmonize with local heritage and community values. Similarly, Jeon et al. [16] demonstrated that place-based contexts strongly influence behavioral responses to subtle environ-

mental cues, reinforcing the importance of tailoring lighting design to specific urban and cultural realities.

2.2. Lightscape and Urban Identity

Nighttime illumination plays a vital role in defining urban landscape quality, public safety, and night identity. The concept of a "lightscape"—the holistic, designed illumination of urban spaces—extends beyond basic functional street lighting to encompass psychological, aesthetic, and cultural dimensions [17,18]. Historically, urban illumination evolved from functional safety measures to symbolic expressions of civic identity and urban vitality [18].

Contemporary research emphasizes that strategic lightscapes can transform underutilized public areas, extend social life into the evening hours, and foster positive emotional connections with urban spaces [19]. Well-designed lightscapes enhance perceived safety, which directly encourages foot traffic and public lingering—prerequisites for informal civic interaction and community bonding [20–22].

In historical and heritage settings, the role of lightscapes is particularly sensitive. As Zielinska-Dabkowska [17] points out, improper lighting can obscure architectural authenticity or degrade cultural atmosphere, whereas sensitive, high-quality illumination elevates architectural heritage, enhances visual appreciation, and reinforces community pride [22]. Lightscapes therefore serve as a powerful environmental medium connecting physical urban structures with citizen perception.

2.3. Place Attachment and Civic Participation

Place attachment, the emotional and cognitive bond formed between individuals and specific geographic settings that is a well-established predictor of civic engagement and pro-environmental action [23]. In urban contexts, residents who possess stronger place attachment demonstrate a greater propensity to participate in local governance, community preservation, and voluntary neighborhood activities [24].

Structural equation modeling studies demonstrate that place attachment, along with place identity and perceived collective efficacy, acts as a primary psychological bridge translating physical neighborhood attributes into civic action [24,25]. Multidimensional models of place attachment highlight that symbolic and cultural dimensions of environment are crucial for triggering civic responsibility [26,27]. When environmental design interventions enhance the visual quality, legibility, and emotional resonance of a neighborhood, they reinforce residents' place identity, which in turn correlates positively with their willingness to engage in collaborative community initiatives.

2.4. Cultural Heritage and Community Development in the Japanese Context

Cultural heritage preservation in contemporary urban development extends far beyond physical conservation [28,29]. Heritage sites act as anchors of collective memory, fostering social cohesion and civic identity in rapidly modernizing cities [30,31]. Modern urban conservation paradigms advocate for "heritage-led regeneration," wherein historical assets are actively integrated into contemporary social and economic life rather than maintained as static museum artifacts [32].

In Japan, the connection between cultural heritage, spatial design, and community involvement possesses distinct characteristics. Japanese urban planning relies heavily on "machizukuri" (bottom–up, community-based town-making), a framework that emphasizes resident participation, local identity, and mutual aid [33]. Amid severe demographic shifts and rural/urban transitions, Japanese local governments increasingly seek innovative ways to activate cultural assets to rebuild community cohesion. Strategic spatial interventions—such as modern lightscapes applied to historical structures—offer a com-

pelling avenue to reconnect residents with local heritage, making cultural assets active catalysts for collaborative civic participation.

3. Theoretical Framework and Hypotheses

3.1. Conceptual Model

Drawing on the literature, we propose a theoretical model positioning lightscape interventions as a key mediating mechanism connecting urban spatial resources to collaborative participation intentions. The model synthesizes principles from nudge theory, environmental psychology, place attachment, and cultural heritage studies to explain how environmental design features can foster civic engagement through non-coercive behavioral pathways.

The theoretical framework is grounded in three core premises:

First, physical design features function as behavioral nudges. Nudge theory posits that thoughtfully structured environments alter perceptions and subtle choices without constraining individual freedom [3]. In urban contexts, spatial quality, aesthetic lighting, and cultural visibility act as ambient cues that render community involvement more psychologically accessible and appealing.

Second, cultural heritage assets provide symbolic meaning that anchors place attachment. Heritage resources foster collective identity and civic pride [29,32]. However, heritage assets do not automatically generate active civic participation; their social activation depends on how they are experienced and integrated into daily life.

Third, lightscape interventions enhance the experiential quality and visibility of urban and cultural assets. Night illumination extends public space usage, highlights historical structures, and generates memorable collective experiences [17]. Lightscapes serve as a design medium that translates physical urban investments and cultural heritage into active community engagement.

Based on these premises, we formulate a framework consisting of a direct-effects model and an extended mediation model. The direct-effects model evaluates whether urban development and cultural heritage assets independently relate to collaborative participation intention. The extended model tests whether lightscape interventions mediate these relationships.

3.2. Research Hypotheses

The direct-effects model tests the linear associations of urban development and cultural heritage assets with collaborative participation intention. Upgraded public space design and cultural assets enhance local identity, thereby fostering positive participation intentions.

Direct Effects Hypotheses:

H1. *Urban development has a positive direct relationship with collaborative participation intention.*

H2. *Cultural heritage assets have a positive direct relationship with collaborative participation intention.*

The conceptual model of direct effects is illustrated in Figure 1.

The extended model incorporates lightscape interventions as a mediating mechanism. Strategic illumination increases space legibility, visual appeal, and emotional attachment, which in turn reinforces citizens' willingness to engage in community initiatives [34].

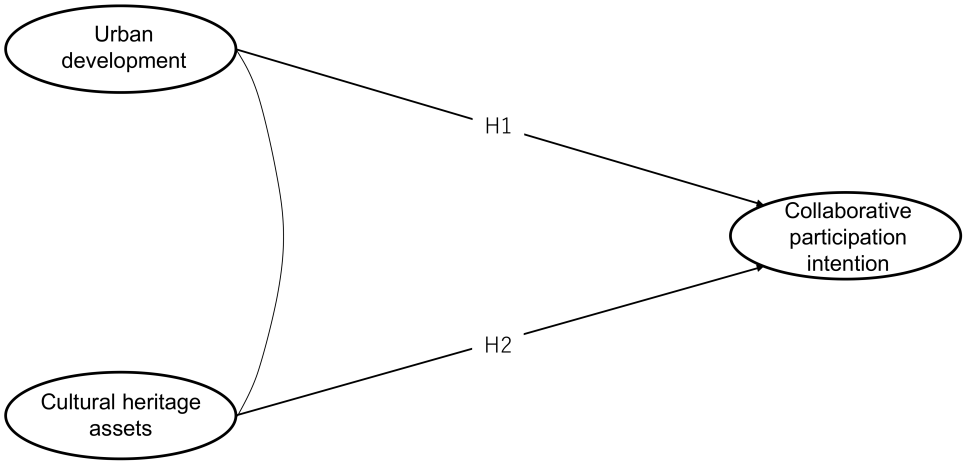


Figure 1. Conceptual Model of Direct Effects.

Extended Mediation Hypotheses:

H3. *Urban development has a positive relationship with lightscape interventions.*

H4. *Cultural heritage assets have a positive relationship with lightscape interventions.*

H5. *Lightscape interventions have a positive relationship with collaborative participation intention.*

H6. *Lightscape interventions mediate the relationship between urban development and collaborative participation intention.*

H7. *Lightscape interventions mediate the relationship between cultural heritage assets and collaborative participation intention.*

Figure 2 demonstrates the relationships among the relevant four variables.

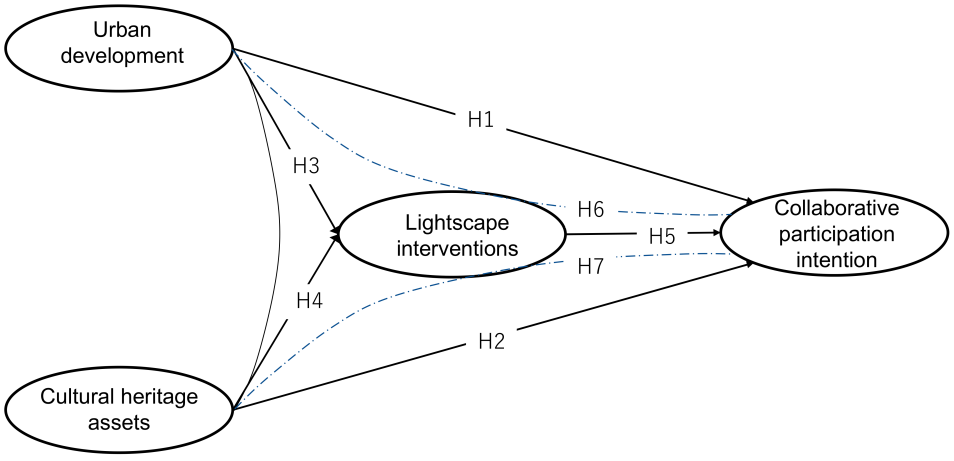


Figure 2. Conceptual Model of Lightscape Interventions.

4. Methodology

4.1. Sampling and Data Collection

A cross-sectional online survey titled "Survey on Spatial Design and Nudge Effects" was administered to urban residents in Japan. To ensure geographic representation across major macro-urban regions, a stratified sampling procedure recruited 720 participants equally from three major metropolitan areas: Kanto (n = 240, 33.3%), Chubu (n = 240, 33.3%),

and Kinki (n = 240, 33.3%). All respondents resided in cities with populations exceeding 100,000, ensuring direct familiarity with urban design and heritage management contexts.

The sample maintained a balanced gender distribution (50.4% male, 49.6% female). Age distribution covered major adult cohorts: 20s (11.8%), 30s (20.3%), 40s (24.2%), 50s (22.8%), and 60s (21.0%). While younger adults (20s) and extreme age cohorts (<18, >70) were slightly underrepresented—a recognized demographic limitation of online panel sampling—the sample provided sufficient statistical power and external validity for urban populations in Japan. Table 1 summarizes the demographic characteristics.

Table 1. Demographic Profile.

		Frequency	Percentage	Cumulative Percentage
Area	Kanto	240	33.3	33.3
	Chubu	240	33.3	66.7
	Kinki	240	33.3	100.0
	Total	720	100.0	
Gender	Male	363	50.4	50.4
	Female	357	49.6	100.0
	Total	720	100.0	
Age	20s	85	11.8	11.8
	30s	146	20.3	32.1
	40s	174	24.2	56.3
	50s	164	22.8	79.0
	60s	151	21.0	100.0
	Total	720	100.0	
Education	Graduate	51	7.1	7.1
	Under graduate	355	49.3	56.4
	Junior College	67	9.3	65.7
	Vocational School	71	9.9	75.6
	High school	153	21.3	96.8
	Middle school	12	1.7	98.5
	Other	11	1.5	100.0
	Total	720	100.0	

Table 2 shows that the descriptive statistics indicate generally positive attitudes toward urban design, cultural heritage, and community-oriented development. Among all items, the highest mean scores were observed for the importance of disaster-prevention-oriented urban design (Q33, M = 3.86), the integration of nature into urban development (Q31, M = 3.75), and the need for systems supporting residents' health and well-being (Q21, M = 3.71). These results suggest strong public support for sustainable, human-centered, and resilient urban environments.

Table 2. Descriptive Statistics.

Questionnaire	Mean	Std. Deviation
Q11. Urban development should prioritize design and aesthetics.	3.34	0.33
Q12. The landscape of an urban area increases the social value of that town.	3.39	0.33
Q13. Nighttime lighting of urban areas and cultural/historical assets increases the social value of that town.	3.42	0.33
Q14. More nighttime lighting should be implemented to enhance the town's landscape value.	3.08	0.33
Q15. I like urban nighttime lighting.	3.20	0.34
Q16. Nighttime lighting is important not only for enhancing aesthetics and tourism value but also for crime prevention.	3.68	0.35
Q21. Urban areas need systems that contribute to residents' health and well-being.	3.71	0.32
Q22. More resident involvement is needed in urban development and design.	3.43	0.34
Q23. I want to be more involved in urban development and design myself.	2.93	0.34
Q24. Urban development and design must be conducted more strategically than ever to promote community revitalization.	3.35	0.33
Q31. Urban development should aim for designs that integrate with nature, such as street trees, waterways, and streams.	3.75	0.34
Q32. Urban development should be human-centered while also prioritizing the theme of coexistence between nature and humans.	3.63	0.35
Q33. From the perspective of disaster prevention and mitigation, such as flood control and fire spread prevention, the maintenance of street trees and the placement of waterways are indispensable in urban development.	3.86	0.36
Q41. Enhancing the aesthetics of urban areas and strategic design lead to the creation of new cultural value.	3.53	0.34
Q42. Urban areas should not only have value as residential and business districts but also serve as "places" where residents and visitors co-create cultural value.	3.51	0.34
Q43. Actively participating in creating new cultural value in urban areas is a role for citizens.	3.30	0.31
Q51. Urban areas are places for interaction between citizens and visitors.	3.34	0.33
Q52. Urban development should possess a community identity.	3.39	0.33
Q53. Urban development should value individuality and design, not just functionality.	3.42	0.33
Q54. Nighttime lighting in urban areas contributes to design and aesthetics, helping establish identity.	3.32	0.33
Q61. Nighttime lighting enhances citizens' and visitors' interest in and attachment to the urban area or historic site.	3.33	0.34
Q62. The presence of well-designed urban areas or historic sites increases one's desire to contribute to those areas.	3.49	0.34
Q71. I would like to participate in creative events using light and video.	3.18	0.45
Q72. Such events provide tourists visiting the area with a fantastical experience.	3.53	0.39
Q73. These innovative events bring new value to historical structures like World Heritage sites.	3.33	0.38
Q74. Innovative events where one can wander around the illuminated site and linger in its afterglow become excellent tourism resources.	3.47	0.38
Q75. Light heals people's hearts and brings them happiness.	3.57	0.35

Respondents also expressed favorable views regarding the social and cultural value of urban landscapes, heritage assets, and lighting interventions. In particular, nighttime lighting was recognized not only for aesthetic enhancement but also for crime prevention (Q16, M = 3.68), while innovative light-based events were perceived as providing cultural and tourism value (Q72, M = 3.53; Q74, M = 3.47).

However, a notable gap emerged between support for citizen participation and personal willingness to engage. While respondents agreed that greater resident involvement in urban development is necessary (Q22, M = 3.43), their own intention to participate was comparatively lower (Q23, M = 2.93). This finding suggests the presence of a participation gap, highlighting the importance of environmental design interventions that may help translate positive attitudes toward participation into actual participation intentions. Overall, the results provide preliminary support for the study's theoretical proposition that spatial design and cultural interventions may foster stronger community involvement.

To address Common Method Bias (CMB) inherent in single-source online surveys, procedural controls were implemented during survey design: respondent anonymity was guaranteed, item order was randomized across construct blocks, and scale anchors were varied to reduce response pattern bias. Statistically, Harman's single-factor test was conducted prior to model estimation, confirming that no single factor accounted for the majority of covariance among variables.

4.2. Measurement Instruments and Experimental Stimulus

Measurement constructs were adapted from validated scales in urban planning, environmental psychology, and heritage literature. All items were translated into Japanese and back-translated to verify semantic equivalence, measured on 5-point Likert scales (1 = strongly disagree, 5 = strongly agree).

To address potential selection bias regarding how online participants evaluate physical lighting and spatial design, a standardized visual stimulus was introduced. Prior to responding to items on lightscape and cultural heritage (Cluster 7), participants viewed a standardized high-definition video demonstrating an innovative lightscape intervention at Nijo Castle (a UNESCO World Heritage site in Kyoto). The video showcased projection mapping and ambient light installations created by the design group "1 to 10." This visual stimulus ensured all respondents evaluated spatial lightscape interventions against a consistent, concrete operational benchmark.

Main Latent Constructs and Indicator Items

1. Urban Development (3 items): Evaluates perceptions of human-centered, nature-integrated, and resilient urban planning (items q3_1, q3_2, q3_3).
2. Cultural Heritage Assets (3 items): Evaluates the perceived value and experience of historical heritage when integrated with modern design and events (items q7_2, q7_3, q7_4).
3. Lightscape Interventions (3 items): Measures positive affect, aesthetic appreciation, and place attachment fostered by urban night illumination (items q1_4, q1_5, q6_1).
4. Collaborative Participation Intention (3 items): Measures willingness to actively engage in civic planning, co-create cultural value, and support local community interaction (items q2_3, q4_3, q5_1).

4.3. Analytical Strategy and Software Justification

Data analysis was performed using Covariance-Based Structural Equation Modeling (CB-SEM) via IBM SPSS AMOS 27.0. AMOS 27.0 was selected due to its established reliability in testing complex latent mediation models, evaluating direct and indirect path coefficients, and providing comprehensive goodness-of-fit diagnostic metrics.

The analytical procedure followed a three-step sequence:

1. Confirmatory Factor Analysis (CFA) to establish measurement model reliability, convergent validity, and discriminant validity.
2. Direct SEM Estimation to evaluate the direct relationships (H1, H2).

3. Extended Mediation SEM Estimation to evaluate mediating mechanisms (H3–H7).

To test the significance of indirect mediation paths (H6, H7), a bias-corrected bootstrapping procedure with 5000 resamples was executed at 95% confidence intervals. Model fit evaluation established criteria and commonly recommended thresholds [35,36]: Chi-square ratio ($\chi^2/df < 5.0$), Goodness-of-Fit Index (GFI > 0.90), Adjusted Goodness-of-Fit Index (AGFI > 0.90), Comparative Fit Index (CFI > 0.95), and Root Mean Square Error of Approximation (RMSEA < 0.08).

5. Results

5.1. Direct SEM Model

The structural equation modeling (SEM) results for the direct-effect model demonstrated a satisfactory overall model fit ($\chi^2 = 79.615$, df = 24, $\chi^2/df = 3.317$, GFI = 0.976, AGFI = 0.955, CFI = 0.984, RMSEA = 0.057), indicating that the proposed structural relationships adequately represented the observed data.

Both direct paths were positive and statistically significant ($p < 0.001$). Urban development exerted a strong positive relationship with collaborative participation intention ($\beta = 0.591$, $p < 0.001$), supporting Hypothesis 1 (H1). Cultural heritage assets also exhibited a significant positive relationship with collaborative participation intention, though with a smaller magnitude ($\beta = 0.181$, $p < 0.001$), supporting Hypothesis 2 (H2).

Among the two predictors in the direct model, urban development emerged as the primary explanatory factor. Overall, the direct model accounted for a substantial proportion of variance in collaborative participation intention ($R^2 = 0.776$).

Table 3 presents the summary of goodness-of-fit indices for both the direct and extended models against standard statistical thresholds.

Table 3. Model Fit Indices for Direct and Extended SEM Models.

Index	Direct Model Figure 3	Extended Model Figure 4	Recommended Threshold	Interpretation
χ^2	79.615	197.862	-	-
df	24	48	-	-
χ^2/df	3.317	4.122	<5.0	Acceptable
p-value	0.000	0.000	-	-
GFI	0.976	0.955	>0.90	Good fit
AGFI	0.955	0.927	>0.90	Good fit
CFI	0.984	0.968	>0.95	Good fit
RMSEA	0.057	0.066	<0.08	Acceptable
HOELTER 0.05	329	237	>200	Adequate sample
HOELTER 0.01	389	268	>200	Adequate sample

Table 4 displays the measurement model factor loadings for the direct SEM model. All loadings exceeded the recommended 0.50 threshold and were statistically significant ($p < 0.001$).

Table 4. Factor Loadings and Parameter Estimates for Direct SEM Model.

To		From	Estimate	S.E.	C.R.	*p*	Factor Loadings
Collaborative participation intention	<---	Cultural heritage	0.106	0.025	4.262	***	0.181
Collaborative participation intention	<---	Urban development	0.448	0.043	10.433	***	0.591
q7_2	<---	Cultural heritage	0.947	0.029	32.583	***	0.867
q7_3	<---	Cultural heritage	0.936	0.029	32.529	***	0.866
q7_4	<---	Cultural heritage	1				0.918
q3_3	<---	Urban development	0.953	0.041	23.365	***	0.783
q3_1	<---	Urban development	1				0.84
q3_2	<---	Urban development	1.046	0.04	26.118	***	0.873
q2_3	<---	Collaborative participation intention	1				0.568
q4_3	<---	Collaborative participation intention	1.21	0.089	13.579	***	0.827
q5_1	<---	Collaborative participation intention	1.03	0.08	12.86	***	0.682

S.E. = Standard Error; C.R. = Critical Ratio; *p* = *p*-value; *** $p < 0.001$.The arrow (<---) indicates the direction of the estimated relationship in the SEM model.

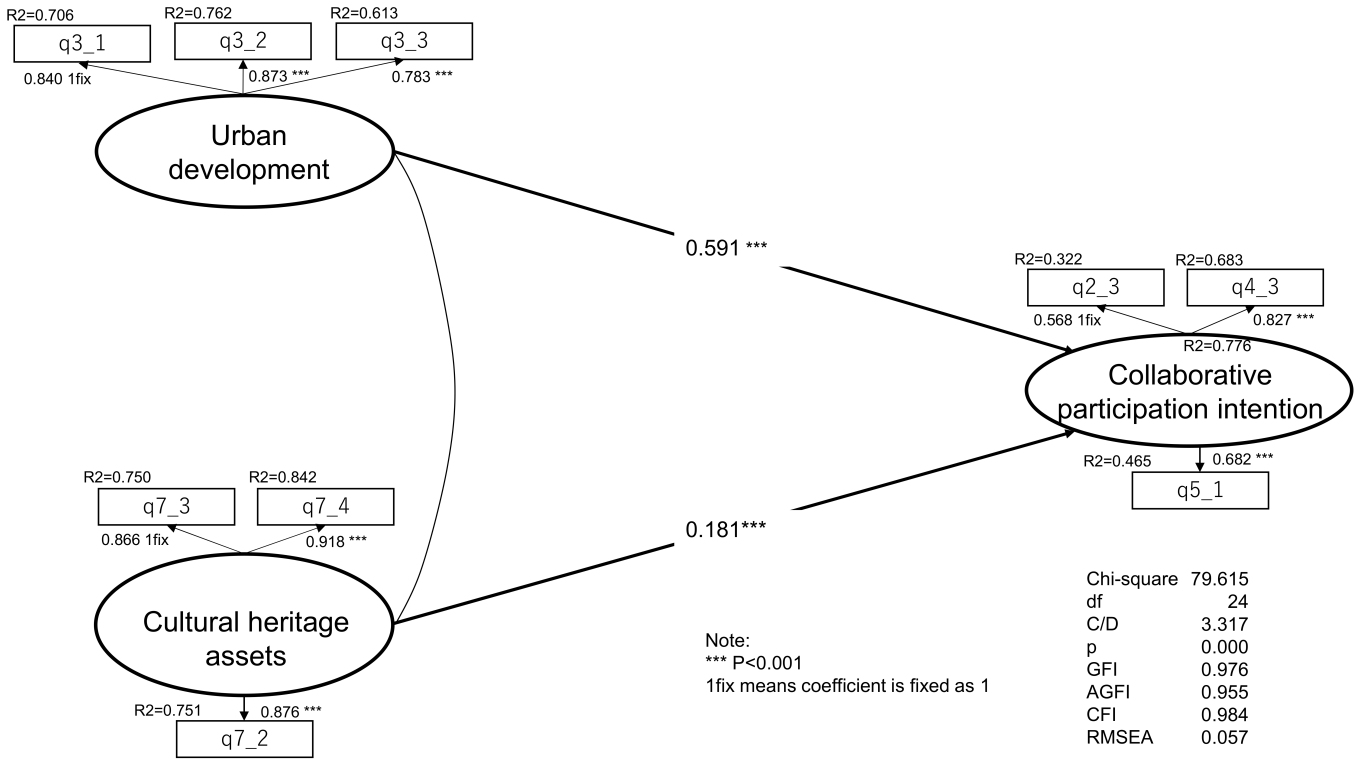


Figure 3. Direct SEM Model of Collaborative Participation Intention.

5.2. Extended SEM Model with Lightscape Interventions

The extended structural equation model incorporating lightscape interventions demonstrated acceptable fit (χ^2 = 197.862, df = 48, p = 0.000, χ^2/df = 4.122, GFI = 0.955, AGFI = 0.927, CFI = 0.968, RMSEA = 0.066) as shown in Figure 4.

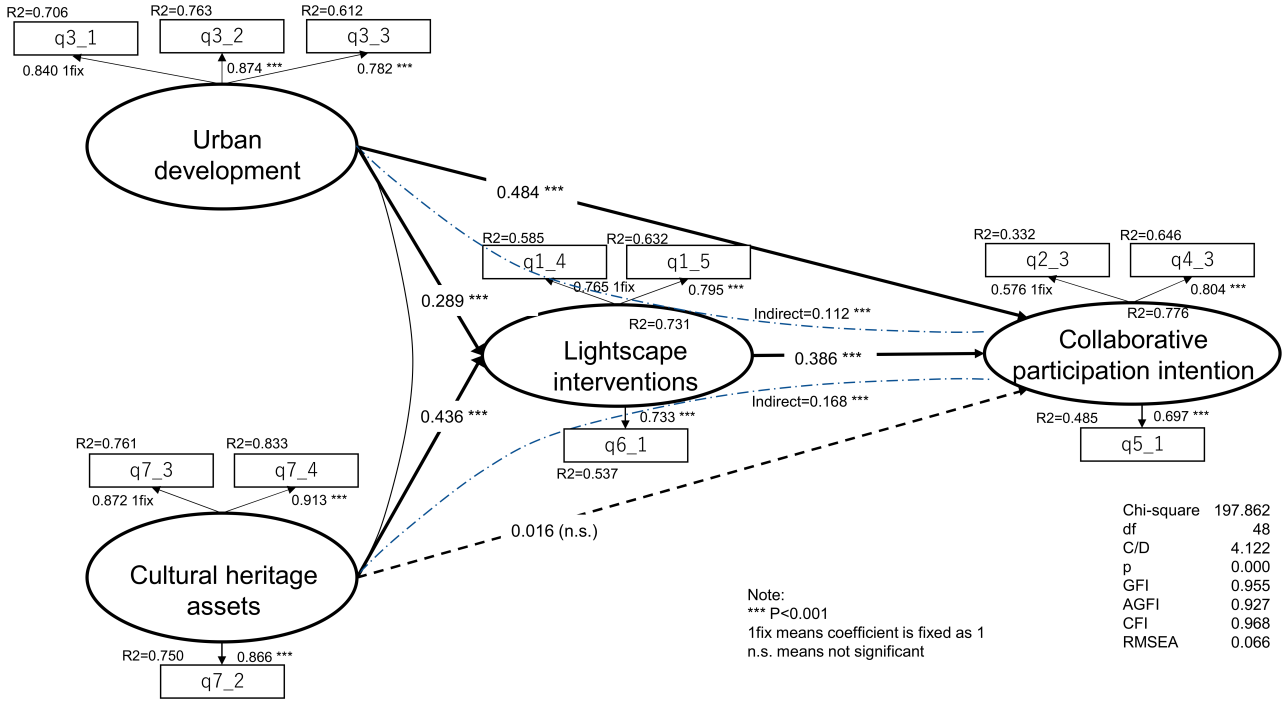


Figure 4. Extended SEM Model with Lightscape Interventions.

The empirical path outcomes for the extended model revealed significant structural nuances:

- Urban development retained a significant direct positive relationship with collaborative participation intention (β = 0.484, $p < 0.001$), supporting H1.
- Direct path from cultural heritage assets to collaborative participation intention became statistically non-significant (β = 0.016, $p = 0.729$), leading to the rejection of H2 in the extended model framework.
- Urban development was positively associated with lightscape interventions (β = 0.289, $p < 0.001$), supporting H3.
- Cultural heritage assets demonstrated a particularly strong positive relationship with lightscape interventions (β = 0.436, $p < 0.001$), supporting H4.
- Lightscape interventions showed a strong positive relationship with collaborative participation intention (β = 0.386, $p < 0.001$), supporting H5.

Table 5 provides the complete structural regression weights and factor loadings for the extended model. The corresponding measurement items and their wording are provided in Appendix A.

Table 5. Structural Path Estimates and Factor Loadings for Extended SEM Model.

To	Direction	From	Estimate	S.E.	C.R.	*p*	Factor Loadings
Lightscape interventions	<---	Urban development	0.302	0.046	6.641	***	0.289
Lightscape interventions	<---	Cultural heritage assets	0.352	0.035	9.98	***	0.436
Collaborative participation intention	<---	Cultural heritage assets	0.009	0.027	0.347	0.729	0.016

Table 5. *Cont.*

To	Direction	From	Estimate	S.E.	C.R.	*p*	Factor Loadings
Collaborative participation intention	<---	Lightscape interventions	0.284	0.042	6.808	***	0.386
Collaborative participation intention	<---	Urban development	0.373	0.04	9.216	***	0.484
q2_3	<---	Collaborative participation intention	1				0.576
q4_3	<---	Collaborative participation intention	1.16	0.083	13.996	***	0.804
q5_1	<---	Collaborative participation intention	1.037	0.078	13.239	***	0.697
q1_4	<---	Lightscape interventions	0.961	0.05	19.177	***	0.765
q1_5	<---	Lightscape interventions	1				0.795
q6_1	<---	Lightscape interventions	0.84	0.045	18.514	***	0.733
q7_2	<---	Cultural heritage assets	0.951	0.029	32.535	***	0.866
q7_3	<---	Cultural heritage assets	0.948	0.029	32.931	***	0.872
q7_4	<---	Cultural heritage assets	1				0.913
q3_1	<---	Urban development	1				0.840
q3_2	<---	Urban development	1.048	0.04	26.179	***	0.874
q3_3	<---	Urban development	0.952	0.041	23.343	***	0.782

Note: S.E. = Standard Error; C.R. = Critical Ratio; *p* = *p*-value; *** $p < 0.001$. The arrow (<---) indicates the direction of the estimated relationship in the SEM model.

5.3. Mediation Analysis (Bootstrapping)

Bias-corrected bootstrapping with 5000 resamples evaluated the indirect mediation pathways (Table 6).

Table 6. Bootstrap Indirect Effect Results (5000 Samples).

Mediation Path	Estimate	SE	95% CI Lower	95% CI Upper	*p*
Urban development → Collaborative participation intention	0.112	0.031	0.060	0.180	0.000
Cultural heritage assets → Collaborative participation intention	0.168	0.034	0.108	0.241	0.000

Urban development exhibited a significant indirect effect on collaborative participation intention through lightscape interventions (β= 0.112, 95% CI (0.060, 0.180], $p < 0.001$), confirming partial mediation (H6).

Cultural heritage assets displayed an even stronger indirect effect on collaborative participation intention through lightscape interventions (β= 0.168, 95% CI (0.108, 0.241), $p < 0.001$). Because the direct path became non-significant in the extended model, this confirms full mediation for cultural heritage assets (H7).

6. Discussion

6.1. Theoretical Contributions and Interpretation of Results

The empirical findings provide important insights into how spatial design features operate as environmental nudges associated with civic participation intentions. Before elaborating on theoretical contributions, we explicitly state the inferential limitations of our cross-sectional design. The structural pathways identified reflect strong statistical

associations aligned with nudge theory predictions rather than established definitive causal chains.

With this qualification, our results yield several theoretical contributions:

First, the findings demonstrate that spatial nudges operate differently depending on the asset type. For urban development, spatial design maintains both a strong direct relationship with civic participation intention (β= 0.484) and an indirect relationship mediated by lightscapes (β = 0.112). This indicates that physical, sustainable, and functional urban planning directly encourages citizens' willingness to engage in community affairs ("machizukuri").

Second, a key insight emerges regarding cultural heritage assets. In the extended model, the direct path from cultural heritage to participation intention became non-significant (β = 0.016, p = 0.729), whereas its structural path to lightscape interventions was exceptionally strong (β= 0.436, $p < 0.001$), resulting in a significant indirect mediation effect (β = 0.168). This confirms a full-mediation mechanism for heritage assets. In substantive terms, historical heritage assets alone do not automatically translate into active civic engagement intentions. Instead, their community value remains latent until activated through experiential, visual design interventions such as lightscapes. Local communities view night illumination as highly compatible with historical assets, turning static heritage into an active catalyst for civic attachment.

Third, we address the operationalization of our construct labelled "Cultural Heritage Assets." Because the indicator items relied partly on event-based and visual experiences (e.g., projection mapping at Nijo Castle), there is a recognized conceptual proximity between heritage experience and lightscape interventions. This partial overlap indicates that our construct captures the perceived value of heritage *as experienced through spatial design and events*, rather than heritage in an isolated, static architectural sense.

6.2. Practical Implications for Urban Planning in Japan

Our findings offer practical implications for local governments and urban planning practitioners, particularly within Japanese urban contexts:

One. Heritage Activation via Lighting: Given Japan's aging urban centers and traditional heritage sites, cities often struggle to engage younger residents in preservation. Thoughtfully designed lightscape interventions serve as cost-effective nudges that revitalize heritage sites without physical alterations, attracting citizens and building local pride.

Two. Bridging the Participation Gap: The descriptive statistics highlighted a gap between general support for community involvement and personal participation intention. Non-coercive spatial nudges—such as inviting, illuminated night public spaces that lower psychological barriers, encouraging residents to transition from passive observers to active participants in local community initiatives.

6.3. Limitations and Future Research

Several limitations should be noted:

First of all, Cross-Sectional Data & Causality: As data were collected at a single time point, causal relationships cannot be definitively proven. Future research should utilize longitudinal designs or pre-/post-installation field experiments.

Second, Demographic Skew: Younger cohorts (20s at 11.8%) and extreme age groups (<18, >70) were relatively underrepresented due to online panel sampling. Future studies should employ targeted offline sampling to capture older demographic perspectives.

Third, Measurement Overlap & Method Bias: Self-reported survey data carries inherent Common Method Bias risks. While procedural controls and Harman's single-factor

test indicated CMB was not a pervasive threat, future studies should incorporate objective behavioral metrics (e.g., actual foot traffic or event attendance logs).

7. Conclusions

This study investigated how spatial design, specifically lightscape interventions, functions as a behavioral nudge associated with collaborative participation intention across urban communities in Japan. Utilizing structural equation modeling (SEM) on data from 720 urban residents, we tested both a direct-effects model and an extended mediation model.

The findings demonstrate that spatial nudges operate through distinct mechanisms based on urban asset types. While urban development exhibits both direct and indirect relationships with civic participation intention, cultural heritage assets operate entirely through a full-mediation pathway via lightscape interventions. Local communities perceive lighting interventions as highly compatible with historical assets, demonstrating that spatial design serves as a vital non-coercive medium that activates latent cultural heritage into meaningful drivers of civic engagement intention.

For urban planners and policymakers, these results highlight strategic lighting as an effective, non-coercive, and cost-effective design tool for community regeneration. By transforming static urban and historical environments into emotionally resonant public spaces, lightscapes strengthen place attachment and foster collaborative civic participation. This finding is consistent with previous research emphasizing the importance of citizens' motivation and participation intention in urban planning [37].

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Appendix A. Survey Items Used in SEM Analysis (Japanese and English Operationalization)

Construct	Item Code	Measurement Item Wording
Urban Development	q3_1	Urban development should prioritize designs integrated with nature, such as street trees and waterways.
	q3_2	Urban development should be human-centered while prioritizing the theme of coexistence between nature and humans.

Construct	Item Code	Measurement Item Wording
	q3_3	Trees and waterways are indispensable in urban development for disaster prevention and mitigation.
Cultural Heritage Assets	q7_2	Such events transcend night illumination to provide tourists with fantastical experiences.
	q7_3	These innovative events bring new value to historical structures like World Heritage sites.
	q7_4	Innovative events where one can wander illuminated sites become excellent tourism resources.
Lightscape Interventions	q1_4	More nighttime lighting should be implemented to enhance the town's landscape value.
	q1_5	I like urban nighttime lighting.
	q6_1	Nighttime lighting enhances citizens' and visitors' interest in and attachment to the urban area or historic site.
Collaborative Participation Intention	q2_3	I want to be more involved in urban development and design myself.
	q4_3	Actively participating in creating new cultural value in urban areas is a role for citizens.
	q5_1	Urban areas are places for interaction between citizens and visitors.

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