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A Methodological Framework for Evaluating Adaptive Space and Inclusive Design in Exhibition Halls: A Multi-Case Application in Wuhan, China

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Abstract

Contemporary cultural infrastructure globally faces a critical architectural challenge: balancing the demand for spatial adaptability (e.g., flexible layouts, interactive technologies) with the absolute necessity of inclusive access for diverse demographics. This tension is particularly acute in rapidly urbanizing environments. However, current research lacks integrated methodologies to systematically evaluate these intersecting issues. This paper addresses this gap by developing a systematic, multi-method framework for post-occupancy evaluation (POE). To empirically illustrate and test the applicability of this framework, a comparative multi-case study was conducted in Wuhan, China, focusing on two distinct exhibition hall typologies within the Hubei Science and Technology Museum and the Qintai Art Museum. Grounded in environmental psychology, the methodology systematically triangulates spatial mapping, behavioral observation, and semi-structured interviews. The empirical application reveals that while highly adaptive elements enhance curatorial flexibility, they frequently introduce unintended cognitive barriers that disproportionately exclude vulnerable visitor groups. For the international research community, this study contributes a culturally responsive evaluation protocol, providing researchers with operational tools to systematically decode the socio-spatial frictions between adaptable exhibition design and universal inclusivity.

Keywords: adaptive space; inclusive design; exhibition halls; methodological framework; environmental psychology; user experience; urban regeneration; China

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1. Introduction

In the contemporary evolution of cultural infrastructure [1,2], broadly defined here as public-facing institutions such as museums and galleries, architectural design is increasingly driven by the paradigm of "adaptive space." Within these institutions, the specific spatial volumes where visitor curatorial interaction occurs, defined herein as "exhibition halls," are transitioning from static repositories to highly flexible, technology-driven environments, such as touch-free mixed reality (MR) and immersive displays [3,4]. Simultaneously, the imperative of "inclusive design" has gained unprecedented global momentum, demanding that these public spaces remain accessible and cognitively comfortable for an increasingly diverse and aging population [5,6].

A fundamental architectural tension emerges at this intersection: the technological and spatial complexity required for adaptability often inadvertently contradicts the intuitive

simplicity required for universal inclusivity. The recent literature demonstrates that while modular and interactive technologies increase curatorial flexibility, they frequently impose elevated cognitive loads on non-digital-native demographics, thereby creating invisible exclusionary barriers, particularly for elderly and neurodivergent visitors [7,8]. This tension extends beyond specific local contexts, representing a global phenomenon in contemporary museum design, especially concerning visually impaired or vulnerable demographics [9,10].

However, this dynamic is uniquely magnified within the context of China's rapid, state-led urban regeneration. Chinese cultural infrastructure operates under distinct socio-cultural dynamics, including exceptionally high-density visitor flows and a strong cultural preference for multi-generational, collective family visits. Furthermore, existing evaluation frameworks often rely on Western-centric paradigms that emphasize individual spatial navigation, which may not fully capture the collective spatial negotiation inherent in the Chinese context.

Current exhibition halls in Chinese cities embody a complex interplay of cultural maintenance, technological advancement, and accessibility requirements. With state-led urban renewal initiatives fueling significant expansion of cultural infrastructure and inclusive communities [1,2], the interplay of adaptive space strategies and inclusive design principles has emerged as an increasingly critical issue. Nevertheless, with development timelines and urban densities often heightening the conflict between standardization of architecture and adaptive responses to diverse and changing visitor requirements, it has been found that despite policy initiatives such as the Accessibility Design Code (GB 50763-2012) [5], there remains an important gap between static compliance with accessibility regulations and dynamic visitor experience.

Current approaches to exhibition hall design and accessibility are primarily informed by Western approaches. These approaches, however, inadequately account for specific features of Chinese urban governance structures, cultural values, and urban renewal cycles. Therefore, it has been found that direct application of current methodologies may fail to account for specific exclusionary mechanisms inherent within state-led initiatives. Further, with mainstream scholarship primarily focusing on inclusive design and adaptive space as separate entities, the specific interplays and conflicts between these approaches have been neglected. These issues have hindered an integrated analysis of how diverse populations, with specific abilities, ages, and cultural backgrounds, navigate and make sense of spatial environments that are increasingly flexible and frequently inaccessible. Therefore, with specific methodological and empirical shortcomings identified with current approaches, this study proposes an integrated framework for examining the interplay of adaptive space and inclusive design within exhibition halls in China. The proposed framework has been designed to address three critical interlinked research priorities: (a) establishing an integrated survey methodology that incorporates spatial adaptability and inclusivity through rigorous user evaluations [11]; (b) moving beyond satisfaction-based approaches to examining specific perceptions and patterns of behavior among different user segments; and (c) ensuring cultural sensitivity through specific recognition of urban development and cultural values.

To address these methodological and empirical deficits, this paper presents a comprehensive framework specifically developed to investigate the intersection of adaptive space and inclusive design within Chinese exhibition halls. The proposed framework responds to three interconnected research imperatives: (1) establishing a unified investigative approach that integrates the analysis of spatial adaptability with inclusivity; (2) transcending general satisfaction metrics to systematically capture the granular perceptions and behavioral

patterns of diverse user groups [12]; and (3) ensuring cultural contextual sensitivity that explicitly acknowledges the specificities of Chinese institutional and urban development.

1.1. Research Context and Objectives

Wuhan, a central metropolis of over 12 million residents, serves as a paradigmatic case of the post-industrial transition observed across many major Chinese cities. The city's strategic pivot toward cultural infrastructure has resulted in a wave of rapid museum construction and renovation. However, this accelerated development has highlighted a distinct tension. Policy aspirations advocate for high-quality, accessible public spaces, yet practical implementation often faces severe physical and operational constraints. Crucially, this research treats the Chinese cultural environment not merely as a background setting, but as a structuring element of the inquiry. Chinese exhibition spaces operate under unique socio-cultural dynamics. These include state-led institutional governance, exceptionally high-density visitor flows during peak seasons, and a strong cultural preference for multi-generational, collective family visits. These specific cultural conditions intensify the demands placed on spatial adaptability and inclusivity, requiring an investigative approach tailored to this environment.

The original contribution of this study is its methodological approach, which enables a rigorous investigation of these research questions. By examining spatial characteristics, behavioral interactions, and differential impacts, a comprehensive evaluation can be achieved within a specific cultural context, while establishing a foundation that can be adapted and tested in other similar rapidly urbanizing environments, subject to local socio-cultural recalibration.

To systematically address these complexities, the research is structured around three distinct analytical axes. These axes underpin the methodology and ensure a robust investigation:

(Axis 1: Spatial Determinants—RQ1): What specific inclusive design factors within the physical exhibition environment most significantly mediate the user experience [13]?

(Axis 2: Behavioral Interaction—RQ2): How do visitors perceive and culturally interact with adaptive spatial elements (e.g., flexible layouts, modular displays) during their engagement with exhibits?

(Axis 3: Differential Impact—RQ3): To what extent do integrated, inclusive, and adaptive design strategies differentially affect accessibility outcomes for diverse audience profiles, particularly within the context of collective Chinese cultural habits?

Based on the literature review and theoretical framework detailed in Section 2, this study proposes the following theoretical propositions to guide the qualitative inquiry:

Proposition 1. *The introduction of highly technological adaptive spatial elements, while increasing curatorial flexibility, tends to increase cognitive load, potentially reducing perceived control and comfort for older visitors and those with cognitive impairments.*

Proposition 2. *Inclusive design strategies that rely solely on regulatory compliance (static features) are insufficient to address the dynamic barriers created by reconfigurable exhibition layouts and time-based media.*

This paper's contribution lies in presenting a methodological framework enabling the systematic and rigorous investigation of these questions and propositions. By distinguishing between spatial features (RQ1), dynamic interactions (RQ2), and differential impacts across demographics (RQ3), the framework ensures a holistic evaluation within culturally specific contexts while maintaining the potential for transferability to similar rapidly urbanizing settings.

Value and Outcomes for the Research Community

The primary contribution of this paper is the provision of a rigorously tested methodological architecture. For the broader research community and architectural practitioners, this study delivers three specific outcomes:

A Replicable POE Protocol: It provides a structured Post-Occupancy Evaluation (POE) protocol that systematically bridges the gap between physical spatial metrics (architectural mapping) and subjective human experiences (environmental psychology).

Operationalization of Cognitive Accessibility: It offers qualitative researchers an applied and tested method for measuring "cognitive load" and "perceived control" in spatial environments, moving accessibility studies beyond mere measurement of physical barriers (e.g., wheelchair ramps).

Context-Sensitive Adaptation Tools: It supplies a modular research design capable of evaluating socio-spatial behaviors in high-density, rapidly urbanizing contexts, which can be readily adapted by researchers investigating cultural infrastructures in other emerging global mega-cities.

1.2. Formulation of the Theoretical Framework: A Narrative Review Strategy

To construct a robust theoretical foundation and identify existing research gaps, a systematic literature retrieval protocol was executed. We queried the Web of Science (WoS) Core Collection and Scopus databases using the Boolean search string: ("adaptive architecture" OR "flexible exhibition" OR "dynamic layout") AND ("inclusive design" OR "universal accessibility" OR "cognitive load") AND ("museum" OR "exhibition hall"). The search was strictly constrained to English-language peer-reviewed journal articles published between 2021 and 2026. This specific temporal frame was selected to capture the most recent post-pandemic architectural trends, which have seen a drastic acceleration in the digitalization and spatial reconfiguration of cultural institutions.

After utilizing reference management software (EndNote 21) to remove duplicates, an initial pool of 142 articles was identified. Following a rigorous abstract and full-text screening based on relevance to spatial evaluation, 45 core articles were retained for the final theoretical synthesis. As illustrated in the bibliometric mind map (Figure 1) generated via VOSviewer 1.6.19, the current "State-of-the-Art" predominantly focuses on Western contexts, where adaptive strategies are often evaluated purely from a facility management perspective, or inclusivity is treated merely as physical wheelchair accessibility.

While pioneering scholars have recently introduced sensor-based tracking and Virtual Reality (VR) simulations to evaluate spatial layouts, these practical techniques often overlook the subjective psychological mediators (e.g., perceived control) of vulnerable demographics. Furthermore, there is a conspicuous scarcity of empirical POE (Post-Occupancy Evaluation) studies situated within the context of China's rapid, state-led urban regeneration. Therefore, our study strategically positions itself within this specific niche. By integrating behavioral observation with environmental psychology in the highly institutionalized context of Wuhan's megaprojects, this framework offers a highly original, human-centric counter-narrative to the prevailing technology-first evaluation models. To construct the theoretical foundation and identify existing methodological gaps, a narrative literature review was conducted. Recent peer-reviewed articles (predominantly spanning 2020–2025) across the domains of inclusive design, adaptive architecture, environmental psychology [14], and post-occupancy evaluation (POE) were synthesized. A narrative approach was explicitly selected over a systematic or scoping review because the primary objective was not the exhaustive quantification of the existing literature, but rather the conceptual integration of previously isolated theoretical domains to inform the architecture of a new qualitative methodological framework. This review established the baseline constructs,

such as cognitive load and spatial flexibility, which were subsequently operationalized in the data collection protocols. To ensure high methodological rigor, the construction of this framework was strictly governed by the principle of methodological triangulation. No single data point was treated in isolation. The integration of spatial mapping (documenting the physical constraints), behavioral observation (capturing objective use patterns), and interviews (extracting subjective meaning) creates a robust system of cross-validation. This structure is specifically designed to eliminate the observational bias commonly found in single-method architectural evaluations.

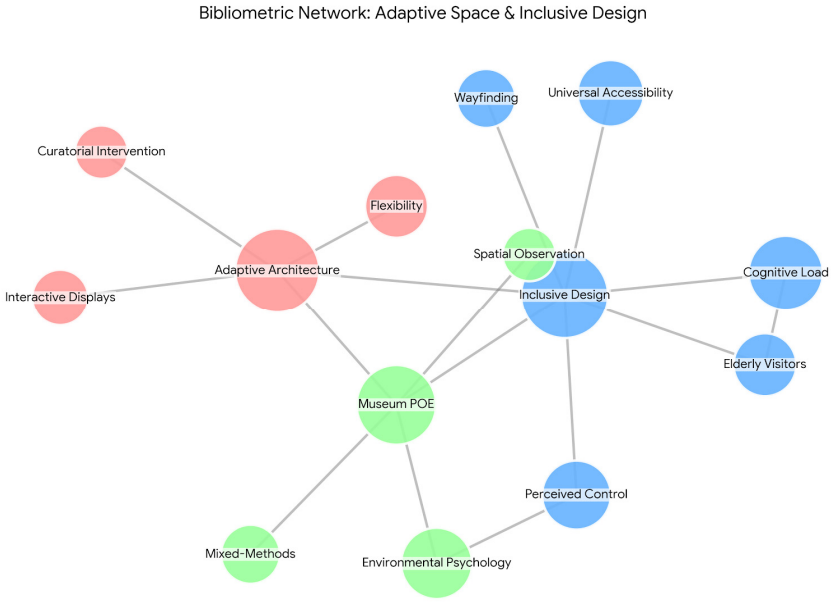


Figure 1. Bibliometric network map of the State-of-the-Art literature (2021–2026) concerning adaptive architecture and inclusive design in exhibition spaces. The network illustrates the predominant research clusters and the existing methodological gap our study addresses. Source: Drawn by the author.

2. Materials and Methods

2.1. Philosophical Positioning

In this study, an interpretivist paradigm is employed, which holds that reality is socially constructed through individuals' interpretation of their experiences within specific contexts [15]. Such an approach is deemed appropriate since tourist experiences, which are of primary interest, are essentially subjective, contextual, and significant constructs that cannot be quantitatively predefined. Therefore, this philosophical approach justifies employing a multi-method qualitative approach. Spatial mapping will define the spatial context, observation will reveal behavioral patterns within this context, and semi-structured interviews will uncover visitors' intrinsic meanings of these experiences. By giving precedence to participants' voices, this approach is consistent with the overall purpose of an interpretivist approach: revealing complex realities of various tourists [16].

2.2. Multiple-Case Comparative Design

The research design of this study is multi-case comparative, in which two exhibition spaces are studied as two separate yet related cases in order to facilitate a rigorous cross-case analysis of the results [15]. This type of research design is especially useful in studying contemporary phenomena in real-world settings because the interface between the phenomenon of interest (user experience) and the environment (adaptive/inclusive space) is dynamic and fluid, thus necessitating multiple sources of evidence.

The selection of case studies in qualitative methodological trials requires careful theoretical replication rather than statistical sampling. To rigorously test the framework's boundaries, two cases, the Hubei Science and Technology Museum and the Wuhan Qintai Art Museum, were selected through purposeful sampling. Scientifically, these institutions were chosen to represent the two opposing typological extremes of China's current state-led cultural infrastructure boom, maximizing variance along three critical parameters:

- Functional and Cognitive Variation: The Science Museum demands high-frequency, interactive cognitive engagement with high-tech adaptive displays. Conversely, the Art Museum relies on contemplative sensory immersion and spatial fluidity. This extreme functional dichotomy allows the framework to be tested against both 'active-technological' and 'passive spatial' accessibility barriers.
- Architectural and Temporal Variation: The Science Museum (completed in 2020) represents a contemporary, purpose-built mega-structure guided by recent adaptive tech trends. The Art Museum represents a highly sculptural, retrofitted spatial concept. This allows the methodology to evaluate how different architectural logics dictate inclusive outcomes.
- Accessibility Implementation Scope: By comparing a space prioritizing dynamic multi-sensory media against a space prioritizing static physical navigation, the trial ensures the proposed environmental psychology indicators (e.g., cognitive load vs. wayfinding) are universally applicable across different institutional intents.

Although only two research sites were selected, they offer sufficient depth of analysis in order to create a thick description of user experience in adaptive spaces while also offering the necessary structural differences in order to evaluate the framework's adaptability. This study also aims to be theoretically reproducible in the sense that, although the specific manifestations of user experience barriers may vary between different research sites (e.g., cognitive load in science spaces versus physical navigation in art spaces), the underlying theoretical mechanisms by which adaptive spatial features relate to inclusive outcomes will remain the same.

Architectural Context of the Selected Cases. To substantiate the spatial mapping procedures, brief architectural profiles of the two cases are necessary. The Hubei Science and Technology Museum (a purpose-built facility completed in 2020) features a monumental, high-tech central atrium radiating into large, flexible exhibition halls. These spaces are specifically designed for high-density, interactive science communication. Its adaptive elements primarily include modular digital displays, reconfigurable interactive zones, and dynamic lighting systems. Conversely, the Qintai Art Museum (a contemporary concrete structure with retrofitted spatial concepts) presents a highly sculptural, terraced spatial sequence. Its adaptive strategies rely heavily on movable partition walls and modulated natural/artificial lighting within a continuous, fluid gallery layout, prioritizing immersive and contemplative experiences.

By translating abstract spatial concepts into tangible architectural illustrations, the methodology ensures transparency and demonstrates exactly how structural constraints map onto the physical footprints of the respective institutions. The specific research strategies are detailed in Table 1.

This phased approach highlights how various techniques were deployed cumulatively to address the research questions. Spatial mapping, which was conducted in September 2025, primarily addressed RQ1 by identifying physical inclusivity factors. Spatial observation, which followed from October to November, captured how visitors interacted with adaptive elements (RQ2). Post-visit interviews, which occurred concurrently from October to December, contextualized the physical and behavioral data with subjective user percep-

tions (RQ3 and RQ1). Finally, an integrative cross-case analysis concluded this empirical trial in December 2025.

Table 1. Data Collection Methods and Research Question Alignment.

Method	Duration/Scope	Primary RQ Addressed	Secondary RQs	Key Outputs
Spatial Mapping	September 2025 Both sites	RQ1 (Inclusivity factors)	RQ2	• Annotated floor plans • Accessibility feature inventory • Adaptive element documentation
Spatial Observation	Oct.–Nov. 2025 72+ h total 12 sessions/site	RQ2 (Adaptive element interaction)	RQ1, RQ3	• Behavioral logs • Route traces (40–60 total) • Barrier documentation • Density heat maps
Visitor Interviews	Oct.–Dec. 2025 *n* = 30–40	RQ1 (Inclusivity factors) RQ3 (Diverse audience impact)	RQ2	• Transcribed narratives • Perception data • Experience descriptions
Staff Interviews	Oct.–Nov. 2025 *n* = 12–15	RQ2 (Adaptive features explanation)	RQ1, RQ3	• Design intent documentation • Constraint identification • Operational context
Integrated Analysis	December 2025 Cross-case	RQ3 (Combined strategy impact)	RQ1, RQ2	• Thematic findings • Cross-case patterns • Convergent/divergent insights

Source: Authors, based on fieldwork data.

As illustrated in Figure 2, the research design is grounded in a User Space Interaction Framework that conceptualizes the relationship between institutional context, design strategies, and user experience. Macro-level factors inform Design Strategies, which then filter through Environmental Psychology Mediators to produce User Experience Outcomes. This conceptual map guides the comparative analysis, ensuring data collection moves beyond surface-level observation to examine causal flows between design intent and visitor impact.

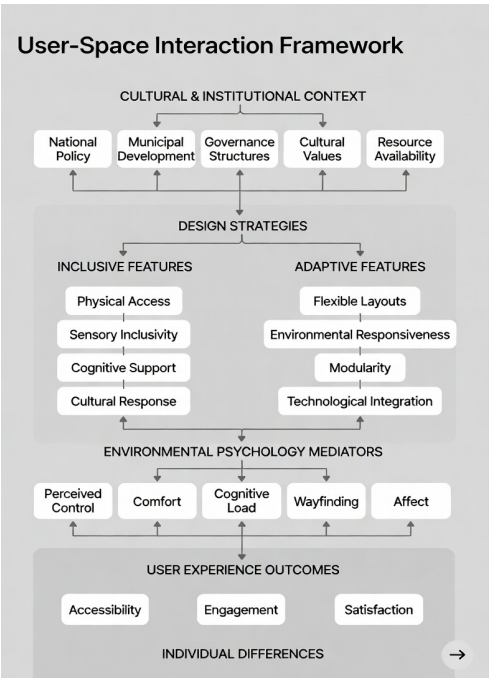


Figure 2. User-Space Interaction Framework. Source: Authors, based on fieldwork data.

2.3. Unit of Analysis and Case Boundaries

The focus of this study is on what we term the visitor experience set, or the specific instances where a person interacts with a built space within a particular zone in a venue. Essentially, this is a deliberate construct to allow us to take a triangular view or a 'slice' view, where we consider physical space, actions, and inner states all at once. This is relevant to our study in that it is in line with the environmental approach to studying this problem. Essentially, this approach is relevant to our study in that it is in line with the environmental approach to studying this problem, as we consider a specific point where variables such as cognition, wayfinding, and comfort are being actively negotiated. To ensure that we stay focused, we set boundaries in space, in time, and in activities. We limit our space to only public space in the exhibition hall, while we exclude office space or backstage, a period of four months that allows us to consider multiple visits in various conditions. Finally, we limit our activities to in-person experience only, while we exclude virtual tours or virtual participation. In terms of what we consider, we focus on physical layout and integrated environmental technology, while we exclude Augmented Reality (AR)/Virtual Reality (VR), which requires equipment that is not part of the built environment.

2.4. Integration Workflow

The process of collecting data combines the three approaches into one coherent case study format rather than treating each of them individually. As shown in Figure 3, the process of collecting data follows a logical order from physical context through behavioral patterns to the meanings of the behaviors.

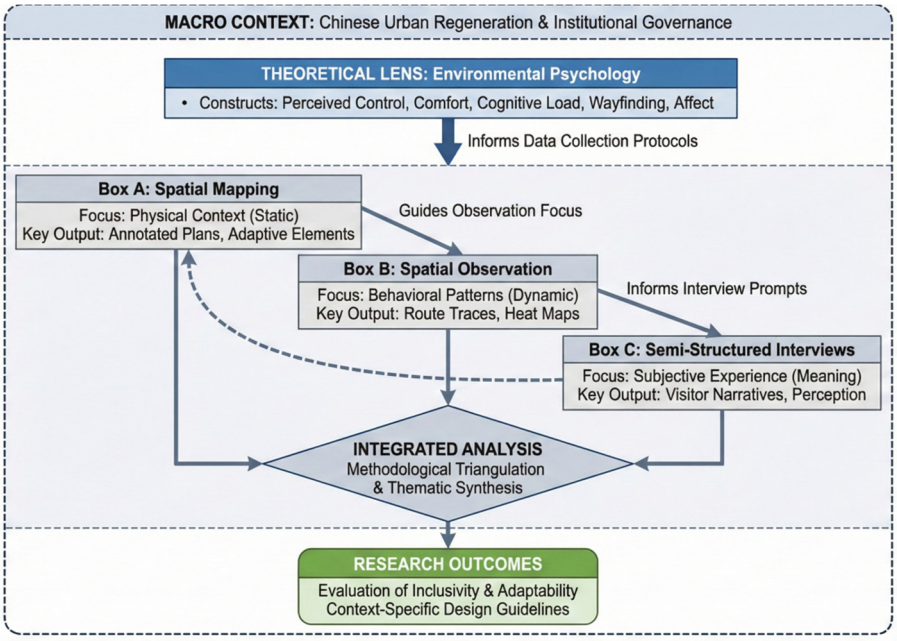


Figure 3. Integrated Methodological Framework for Adaptive and Inclusive Exhibition Design. Source: Authors, based on fieldwork data.

Additionally, the framework makes a methodological contribution by virtue of its unambiguous focus on cultural responsiveness and operational specificity. Through the interplay of inclusive design principles based on Western cultural traditions and the distinctiveness of Chinese institutional governance in terms of state-led development and urban regeneration, the approach moves beyond a mechanistic application towards environmentally sensitive adaptation. This is underscored by the rigorous application of theory-method in the framework, whereby environmental psychological constructs (cogni-

tive load and control, for instance) are used as a conduit to connect theoretical propositions and empirical inquiry. These constructs are used to specify operational protocols, thus addressing criticisms of qualitative design research in terms of a lack of systematic precision. This integrated approach is critical in rapid urban regeneration contexts, where significant gaps emerge between design intent and lived reality. By triangulating the physical, behavioral, and subjective, this framework provides the necessary rigor to evaluate these complex environments.

2.5. Participant Selection and Information Power

Semi-structured interviews were the primary method of tapping into the way users feel, what these feelings mean to them, and the experiences that inform the interpretative lens of this study. While observational methods can inform us about what visitors do, interviews can inform us about why they navigate the space the way they do. This method directly aligns with the theoretical framework of the study, which explores the way the mind processes various experiences, such as perceived control and mental load, which inform the way the space design translates into user satisfaction. This method provides the qualitative component necessary to understand the ways in which the inclusive design strategies inform user experience (RQ1) and the way these strategies impact diverse user groups (RQ3).

The study employed purposive sampling targeting specific demographic segments (e.g., elderly visitors, families with young children, and individuals with mobility constraints) to maximize experiential variation. Given the qualitative nature of the study, the sample size was determined by the principle of "information power" [17] rather than statistical representativeness. Because the study objective was highly specific (evaluating specific spatial interactions) and the sample was deeply engaged (on-site post-visit interviews), a smaller, densely informative sample was deemed sufficient. Theoretical saturation was analytically confirmed when the thematic coding tree stabilized, specifically, after 34 visitor interviews, new data instances fitted existing categories without requiring the generation of new parent codes regarding cognitive load or spatial barriers.

Standard processes ensure the data is solid and the participants are comfortable. After the site visit, interviews take place in a quiet lobby area or via video call, lasting around 30–45 min for visitors and 45–60 min for staff. They are all recorded and transcribed within one week to facilitate repeated analysis. To accommodate the local language, the interviews take place in Mandarin or English, with translation and back-translation checks to ensure meaning is not lost. We also assign consistent, unique IDs to the participants, such as A-V01 for the first participant from the Science Museum Visitor Group, to ensure anonymity and traceability.

Interview questions are not structured around a set Q&A list but instead focus on the study's environmental psychology framework. Questions for the visitors include wayfinding (how easy/difficult the space is to navigate, the usability of the signs), comfort (how the space manages fatigue and the need for rest), accessibility barriers (the functional usability and any difficulties), and engagement (how the adaptive layout is used). Questions for the employee interviews also align with these topics, but instead focus on the supplier side, including the integration of the design intent, any constraints, the evolution of the changes, and the integration of user feedback. When analyzed, the narratives from the interviews provide a crucial triangulation, helping to understand the behavioral patterns observed during the spatial mapping and observation.

Demographic Profile of Interviewees: A total of 34 semi-structured interviews were successfully conducted and analyzed to achieve data saturation. To ensure a comprehensive representation of diverse spatial perspectives and experiential barriers, the participant

cohort was purposefully balanced. As illustrated in Figure 4, the sample comprised 16 males (47.1%) and 18 females (52.9%). Regarding age distribution (Figure 5), the cohort captured responses across generations: 18–25 years (n = 6), 26–40 years (n = 10), 41–60 years (n = 10), and crucially, over 60 years (n = 8). This diverse demographic profile is essential for uncovering age-specific cognitive friction when interacting with highly adaptive spaces.

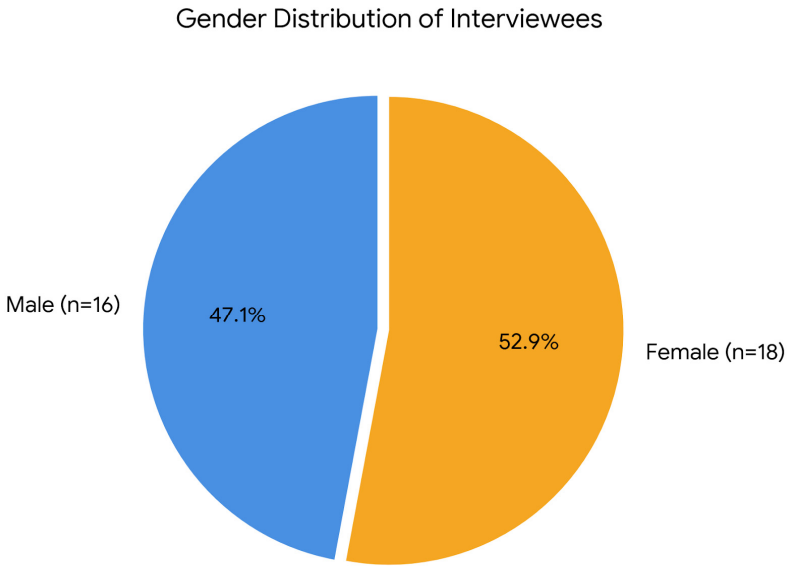


Figure 4. Demographic profile of the 34 interviewees, distributed by gender. Source: Drawn by the author.

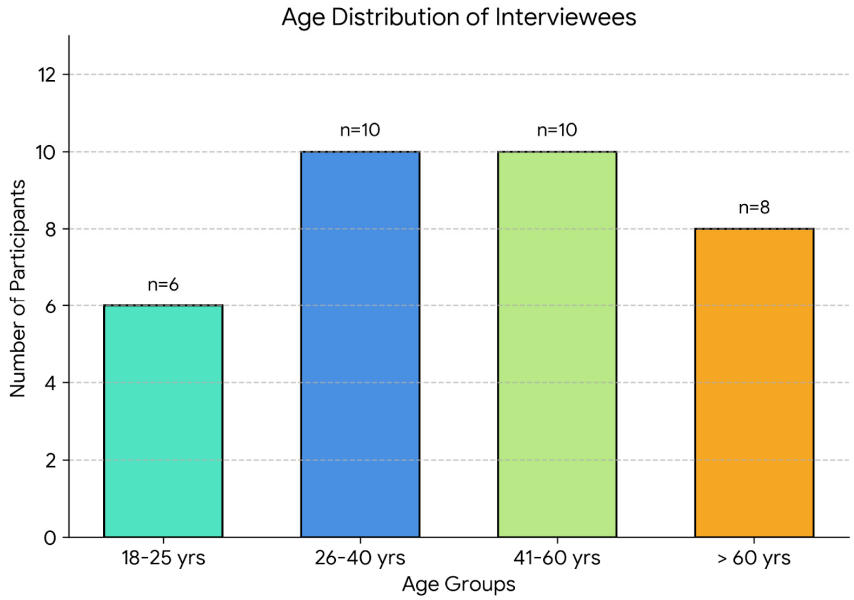


Figure 5. Demographic profile of the 34 interviewees: Age group. Source: Drawn by the author.

2.6. Spatial Observation

The systematic spatial observations were used to collect objective behavioral data that would provide additional information about what visitors would reveal through interviews, which may include their navigation and interactions that they may not even be able to articulate or recognize. Thus, to ensure that the data collected would be representative of normal visitor behavior, the research observed for at least 72 h, which were distributed across 12 sessions for each hall. These sessions were then grouped into four different time blocks, which were weekday mornings, weekday afternoons, weekend mornings, and

weekend afternoons, considering the different crowds that visit the museum, such as school groups and older visitors. Moreover, the observers were positioned in tactically strategic areas, which included the areas around the museum's entrance, threshold areas around the galleries, main routes, and areas around the exhibition spaces, which would allow for the natural flow of visitors to be observed. The research observed and collected data on the four main behavioral themes, which included navigational cues, accessibility issues, user engagement, and crowd avoidance, which were all recorded through logging onto sheets, sketching possible routes, and writing down observations, which were then backed up through non-identifiable photographs. Observations focus on identifying gaps between designed affordances and actual use patterns, particularly regarding adaptive elements. All spatial observations were conducted by two trained researchers simultaneously. Discrepancies in behavioral logs were resolved through immediate post-session debriefings to ensure inter-rater consistency.

Observation Matrix: To capture a holistic view of spatial usage, the 72 h of unobtrusive behavioral observation were strategically distributed across different temporal conditions, yielding distinct demographic dominances (Table 2).

Table 2. Matrix of Observation Periods and Dominant Visitor Profiles.

Temporal Condition	Observation Hours	Hubei Science and Technology Museum (Dominant Profile)	Wuhan Qintai Art Museum (Dominant Profile)
Weekday (Morning)	24 h	School groups, Elderly visitors with grandchildren	Senior citizens, Independent adult visitors
Weekday (Afternoon)	18 h	Families, Young adults	University students, Professionals
Weekend/Free Admission	24 h	Extreme high density: Multi-generational families	High density: Young adults, Tourist groups
Special Events/Evenings	12 h	Young adults (Digital interactive zones)	Art enthusiasts, Organized tour groups

Source: Authors, based on fieldwork data.

Comparative perspective, a similar critical incident was documented at the Qintai Art Museum, illustrating how curatorial interventions can inadvertently compromise the building's inherent inclusivity (Table 3).

Table 3. Narrative of a socio-spatial barrier at Qintai Art Museum.

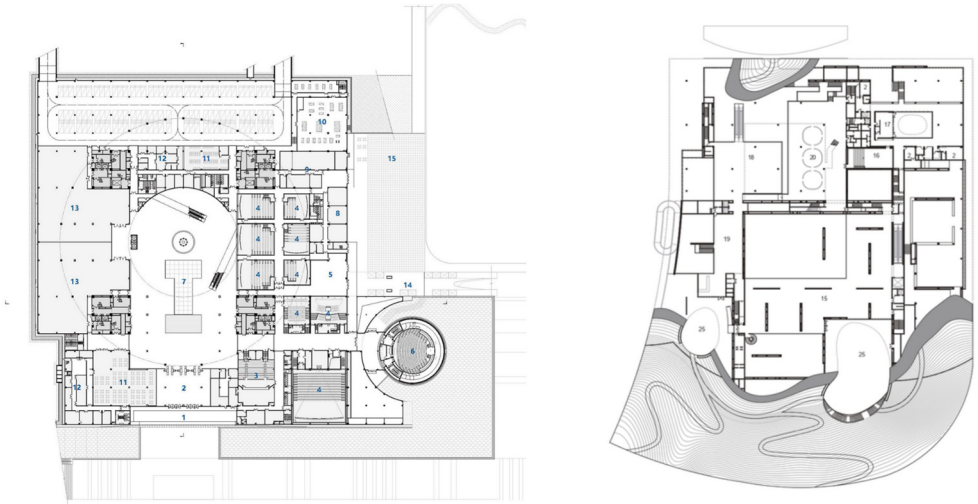
Element	Detailed Description
Subject	A visitor using a manual wheelchair (male, approximately 35 years old), accompanied by a companion.
Setting	Fixed accessible ramp leading to the contemporary art gallery on the second floor of the Art Museum.
Intervention	To coordinate with the "Immersive Art" theme, the curatorial team temporarily placed a set of large, irregular reflective installations (artworks) at the entrance of the ramp. This reduced the effective width of the ramp from 1.5 m to less than 0.8 m.
Behavior	The visitor attempted to enter but found the wheelchair could not pass. The companion tried to move the installation but failed. The visitor eventually chose to abandon the gallery and expressed strong frustration to the companion: "Why is a specially designed path not allowed to be used?"
Analysis	The architect provided the "static inclusivity" (the ramp), but the curatorial team's "dynamic adjustment" pursued visual spectacle at the expense of spatial continuity. This is not only a physical obstruction but also causes a psychological sense of "exclusion."

Source: Authors, based on fieldwork data.

2.7. Spatial Mapping and Analysis

Spatial mapping serves as both a data collection method and a critical analytical tool. It documents the physical layout, accessibility features, and adaptive elements to establish the material context for visitor experiences. This method produces three primary outputs that ground the subsequent analysis: annotated floor plans, visitor route traces,

and barrier documentation grounded in regulatory benchmarks (GB 50763-2012; BSI, 2005) [5,8]. To explicitly overcome the contextual limitation of focusing on only two case studies, this methodology mandates the rigorous visual documentation of the spaces discussed. By translating abstract spatial concepts into tangible architectural illustrations, the methodology ensures transparency and replicability. Readers and practitioners can directly articulate the relationship between the proposed theoretical framework and the physical reality of the exhibition halls. This visual grounding demonstrates exactly how spatial constraints and adaptive elements (such as modular partitions or interactive media zones) map onto the physical footprints of the Qintai Art Museum and the Hubei Science and Technology Museum (Figure 6).



(a)Hubei Science and Technology Museum (b)Wuhan Qintai Art Museum.

Figure 6. Floor plans of the selected cases: (**a**) Hubei Science and Technology Museum; (**b**) Wuhan Qintai Art Museum. Source: Authors, based on fieldwork data and institutional architectural plans.

As an analysis tool, the outputs of the spatial mapping were not limited to description. The outputs were useful for further analysis to evaluate the user experience. The bottlenecks and barriers are tangible evidence of the "Inclusivity Factors" (RQ1), while the adaptive elements are useful for evaluating the "Interactions" (RQ2). The maps were used as a visual aid during the interviews. The participants traced their routes on the map, which helped highlight the difficult or comfortable areas. The mapping helped anchor participants' abstract thoughts during the interview in tangible spatial reality, making the qualitative data more credible.

3. Data Analysis

3.1. Analytical Procedure and Triangulation Protocol

The qualitative analysis adhered to the thematic analysis framework established by Braun and Clarke [18,19]. To ensure methodological transparency and replicability, the coding procedure was highly structured. First, data immersion involved verbatim transcription and familiarization. Second, the initial coding phase generated approximately 135 descriptive open codes across both case studies (e.g., "confusion at interactive screen," "resting on non-seating structures"). Third, during axial coding, these were collapsed into 14 distinct categories guided deductively by the environmental psychology constructs (e.g., Cognitive Load, Wayfinding Friction). Finally, these categories were synthesized into four overarching themes.

To operationalize the "methodological triangulation," data streams were systematically integrated using an audit matrix. Subjective interview transcripts (what visitors said) were cross-referenced with observational behavioral logs (what visitors did) and mapped against the annotated floor plans (the physical spatial constraints). Analytical consistency was maintained through peer debriefing between the researchers and a documented audit trail of coding decisions.

3.2. Illustrative Analytical Trajectory

In order to illustrate the transparency of the coding process, Table 4 provides an example of how the concrete case of the elderly visitor was used to refine the raw qualitative data into abstract themes. The process begins by selecting particular descriptive codes from the raw data, such as "insufficient signage," "fatigue," and "seat delays." The raw data is then grouped into categories, which in this case are "wayfinding challenges" and "physical accessibility gaps." The categories, in turn, are grouped into an abstract theme, which is "The effectiveness of inclusive design is modulated by the comprehensiveness and integration of its implementation." The abstract theme directly answers Research Question 3, which suggests that accessibility is not only determined by the presence of certain features, such as seating, but also by their integration into the overall wayfinding process. Table 2 illustrates the transformation of raw data into themes using a "worked example" of an elderly visitor's experience at the Science Museum. This example specifically highlights the connection between an adaptive element (flashing interactive wall), a behavioral response (avoidance), and a psychological outcome (dizziness, fatigue), directly addressing Proposition 1.

Table 4. Illustrative Analytical Trajectory (Worked Example: Elderly Visitor at Science Museum).

Phase 1: Raw Data (Translated Verbatim Extract)	Phase 2: Initial Codes (Descriptive and In Vivo)	Phase 3: Categories (Axial Coding)	Phase 4: Theme Development (Synthesized)
Participant (Age 68): "I was getting very tired after the second hall. I saw a bench near that big flashing interactive wall, but there were so many young people crowding around the screen, jumping. I couldn't get through. The lights were flashing too fast; it made me dizzy. I just gave up and leaned against the corridor wall for a bit."	Physical fatigue ("getting very tired") Visual access to rest ("saw a bench") Physical barrier to rest ("couldn't get through" due to crowding) Crowding around adaptive element ("crowding around the screen") Sensory overload ("flashing too fast," "dizzy") Behavioral adaptation/Resignation ("gave up and leaned against the wall")	Category A: Conflict between Activity Zones and Rest Zones (Connecting fatigue with the inability to access seating due to other activities) Category B: Sensory and Cognitive Overstimulation (Connecting flashing lights of adaptive media with dizziness and avoidance behavior)	Theme: The implementation of high-intensity adaptive media can create exclusionary zones that compromise basic physical accessibility needs (e.g., rest), particularly for older users. (This theme directly addresses RQ3 regarding differential impacts on diverse audiences.)

Source: Authors, based on fieldwork data.

This rhythm with which this approach will proceed highlights how various techniques can be deployed cumulatively to address various research questions. Spatial mapping, which starts in September 2025, primarily addresses RQ1 by collecting inclusion factors. Spatial observation, which follows from October to November, primarily addresses RQ2 by collecting information on how people engage with adaptive elements. Interviews, which occur from October to December, cumulatively address RQ3 and RQ1 by combining information on the physical and behavioral with information on how people perceive these. Finally, an integrative cross-case analysis concludes this process in December 2025.

3.3. Methodological Rigor and Ethical Considerations

In order to establish the credibility of the research, the study was conducted within the parameters established by Lincoln and Guba [16]. Transferability was ensured through the provision of rich details of the context of the study as well as the clear boundary definitions, which enabled the study to be compared to other urban settings. In addition to this, the reliability of the study was ensured through the provision of a comprehensive audit trail, which critically addressed the researcher's positionality as well as the provision of negative case analysis to ensure that bias was not incorporated within the study.

Ethics approval was sought from the Jawatankuasa Etika Penyelidikan Manusia (Bukan Perubatan) of Universiti Malaysia Sarawak (UNIMAS/NC-21.02/03-02 jll.5(19); 18 July 2025). Informed consent was sought from the participants through the provision of a written consent form that was designed to be simple to read, as well as the provision of alternative means of providing consent due to the varying levels of literacy among the participants, as well as visual impairments. In addition to this, the confidentiality of the participants was ensured through the provision of unique identifiers to ensure the anonymity of the participants. In the collection of digital data, the files were kept within the password-protected cloud storage (Baidu Cloud Drive), while the hard copy files were kept within a storage facility for a period of five years. In the collection of spatial data, the study was made transparent to the participants through the provision of institutional licensing as well as the provision of entrance signage to the research sites to ensure that the participants were made aware of the study while ensuring that the study was not invasive. In the collection of data from the elderly population, the study provided assistance to the elderly to ensure their comfort during the study. In addition to this, the study provided support from people who were empathetic to the elderly population.

4. Results

4.1. Frequency and Typology of Observed Socio-Spatial Barriers

Throughout the 72 h of structured spatial observation across the two venues, specific socio-spatial barriers were meticulously logged and categorized. The data reveal a stark contrast in the typologies of barriers generated by the different adaptive strategies of the two institutions (Table 5).

Table 5. Frequency and Typology of Observed Spatial Barriers (72 h).

Barrier Typology	Specific Observed Incident	Frequency (Science Museum)	Frequency (Art Museum)	Primary Affected Demographic
Technological Overload	Severe congestion caused by visitors lingering at dynamic AR/VR interactive screens, blocking main circulation paths.	47	5	Elderly (>60), Visitors with strollers
Curatorial Intervention	Temporary exhibition partitions or modular art installations physically obstructing standard wheelchair ramps or tactile paving.	4	38	Mobility-impaired, Visually impaired
Sensory Disorientation	Visitors visibly lost or backtracked due to rapidly changing digital signage or high-contrast projection mapping.	52	14	Elderly (>60), First-time visitors
Ergonomic Deficit	Lack of static resting seating within highly fluid, "open-plan" adaptive zones, leading to physical fatigue.	21	45	Elderly (>60), Multi-generational families

Source: Authors, based on fieldwork data.

As quantified in Table 5, the high-tech adaptability of the Hubei Science and Technology Museum predominantly generated barriers related to Sensory Disorientation (52 inci-

dents) and Technological Overload (47 incidents). For instance, dynamic projection zones frequently caused older visitors to freeze in place, unsure of the pathway boundaries.

Conversely, the barriers observed at the Wuhan Qintai Art Museum were largely driven by Curatorial Interventions (38 incidents). Although the building's base architecture strictly complies with accessibility codes (static inclusivity), curators frequently placed temporary, highly aesthetic modular partitions in ways that inadvertently blocked inclusive ramps or obscured fixed wayfinding signs. This quantitative evidence strongly supports the qualitative finding that flexibility, if not systematically managed, directly cannibalizes inclusivity.

4.2. Methodological Synthesis and Contributions

This research offers an all-encompassing methodological framework that aims to mitigate the issues of fragmentation, which are often inherent in the research of multi-method design. This framework does not simply follow the linear progression of separate research operations; rather, it is an operation of periodic integration that encompasses an intrinsically linked theoretical structure, data collection, and analysis results. What this research offers is an integration of spatial mapping, behavioral observation, and interviews, which is unlike the traditional case study research that does not distinctly clarify the relationship between spatial data and behavioral observation, and between behavioral observation and interviews. This research framework is particularly pertinent in the context of China's rapid urban renewal. Rapid development and implementation, which are inherent in China's construction environment, have resulted in an obvious disparity between intended function (mapped content) and actual experience (experienced content). If this research were to rely solely on interviews, it would be able to reveal the level of dissatisfaction among users but would be unable to reveal the specific adaptive mechanisms that cause this level of dissatisfaction. Similarly, if this research were to rely solely on spatial audits, it would be able to reveal the level of compliance with national standards (GB 50763-2012) but would be unable to reveal the level of behavioral frustration and cognitive fatigue that visitors may encounter. This study articulates a comprehensive methodological framework addressing the fragmentation inherent in multi-method design research. As previously illustrated in the methodology section, it operates as a cyclical integration where theoretical constructs, data collection, and analytical outcomes are coupled.

4.3. Empirical Insights from the Trial Cases

Empirical Synthesis and Cross-Case Insights

While the primary focus of this paper is the methodological architecture, the empirical application across the Hubei Science and Technology Museum (purpose-built, high-tech) and the Qintai Art Museum (retrofitted, contemplative) yielded substantive, synthesized findings that demonstrate the framework's utility. While primarily a methodological contribution, the empirical trial successfully isolated specific socio-spatial tensions that traditional evaluations miss. By analyzing the 34 interview transcripts against the 58 behavioral route traces, clear divergent patterns emerged between the two specific cases.

The Paradox of Technological Adaptability (Addressing RQ1 and RQ2)

A recurring pattern identified across both cases was the paradox of technological adaptability. In the Science Museum, highly interactive, reconfigurable digital display zones were intended to maximize engagement. However, triangulated data revealed that these zones frequently resulted in sensory overload and diminished perceived control for elderly visitors. The spatial mapping correlated these specific digital nodes with observed behavioral bottlenecks and instances of rapid visitor withdrawal, illustrating how adaptive complexity inadvertently degrades inclusive access.

Static Inclusivity vs. Dynamic Layouts (Addressing RQ3)

A structured cross-case comparison revealed a critical deficit in current inclusive design practices. Both institutions strictly complied with national physical accessibility codes (GB 50763-2012) regarding static features like ramps and elevator dimensions. However, observational and interview data indicated that these static provisions were routinely compromised by dynamic curatorial adaptations. For example, temporary partition walls in the Art Museum and movable interactive kiosks in the Science Museum frequently encroached upon essential circulation corridors, creating dynamic wayfinding frictions that disproportionately affected visitors with mobility or visual impairments. This finding empirically confirms the theoretical proposition that inclusive design cannot be treated as a static architectural layer, but must be continuously evaluated against the dynamic operational reality of the exhibition space.

Based on these insights, the methodology offers tangible value for design and management:

For Architects and Exhibition Designers (Design-Oriented): Move beyond regulatory checklists towards "Cognitive Impact Assessments" for adaptive elements during the design phase. For example, when designing modular interactive zones, explicitly model the cognitive load for non-digital native user groups and integrate intuitive, non-textual wayfinding cues that function independently of changing digital content.

For Museum Curators and Managers (Operational): Utilize the framework's observation protocols for rapid, periodic "inclusion audits" of temporary exhibitions. Implement feedback loops where operational constraints identified by staff (e.g., maintenance of high-tech features) directly inform future curatorial briefs to prevent accessibility failures.

For Policymakers: The findings suggest a need to update accessibility codes (like GB 50763) to include guidelines not just for static physical access, but for the cognitive and sensory implications of dynamic, digital exhibition technologies in public cultural spaces.

The findings prompt a critical question: Is the identified 'technological adaptability paradox' a failure of architectural design or a consequence of poor operational management? Our observations suggest that the tension frequently arises from a disconnect between Facility Management (FM) and Curatorial Interventions. In both cases, the base architecture provided a 'static inclusive pedestal'—compliant ramps, clear corridors, and logical layouts. However, this foundation was repeatedly compromised by curatorial decisions that prioritized 'visual spectacle' over user orientation. These 'uncontrolled interventions'—such as placing temporary kiosks on main pathways or reconfiguring modular walls without considering wayfinding logic—demonstrate that inclusivity is not a one-time design achievement but a continuous operational commitment. Architects provide the inclusive hardware, but the dynamic software (curation and management) often 'breaks' the system in the name of flexibility.

4.4. Practical Implications and Boundary Conditions

This study operates within specific boundary conditions that mandate a critical reflection on its implications. The primary contextual limitation is the reliance on merely two case studies within Wuhan. While this narrow scope permitted the deep, triangulated qualitative inquiry necessary to illustrate the methodological framework, it inherently restricts the broader generalizability of the empirical findings. The specific socio-cultural dynamics observed, such as multi-generational Chinese visiting habits, mean that the specific spatial behaviors documented here cannot be universally extrapolated to Western institutional contexts without further validation. The framework presented is highly context-dependent; therefore, its broader applicability relies on researchers recalibrating the environmental psychology constructs to match their specific local cultural parameters.

Finally, we must acknowledge the specific institutional context of this study. Both selected cases are situated within a strongly institutionalized, state-controlled environment in China, which significantly shapes both museum operations and visitor behavior. The high degree of 'collective compliance' observed among Chinese visitors who may be more tolerant of spatial inconveniences due to deep-seated respect for public institutions might differ from visitor behaviors in Western contexts, where individual autonomy is often more aggressively asserted. Therefore, while our methodological framework is globally transferable, the empirical findings regarding 'satisfaction' must be interpreted within this specific cultural and political setting. Future studies in non-state-controlled or private museum contexts in Western countries would provide a valuable counterpoint to evaluate the universal applicability of these socio-spatial patterns.

5. Conclusions

This paper has developed, applied, and empirically illustrated a comprehensive methodological framework designed to investigate the complex friction between adaptive spatial strategies and inclusive design. By triangulating spatial mapping, behavioral observation, and psychological interview data within the rapid urban regeneration context of Wuhan, China, the study transcends conventional static architectural auditing [20].

The empirical trial of this framework across the two contrasting case studies yielded a critical insight: spatial adaptability does not naturally equate to human inclusivity. In fact, the pursuit of highly flexible, technology-driven exhibition spaces often generates hidden cognitive and sensory barriers, particularly for vulnerable demographics. The scientific value of this framework lies in its integrated capacity to make these invisible barriers visible, measurable, and geographically contextualized. For the international research community, this methodology offers a robust evaluation protocol that can be adapted and tested in other contexts. While the specific socio-cultural behaviors observed in Wuhan cannot be universally transferred without limitations, the underlying methodological architecture correlating physical affordances with psychological impact provides a critical step toward ensuring that the museums of the future are not only technologically adaptable but genuinely inclusive.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The qualitative data supporting this study (interview transcripts and observational logs) are not publicly available due to ethical restrictions regarding participant privacy and confidentiality. Blank data collection instruments are available from the corresponding author upon reasonable request.

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