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SUSTAINABLE HOUSING DEVELOPMENT THROUGH BIOPHILIC DESIGN: STAKEHOLDER PERSPECTIVES OF DEVELOPERS AND RESIDENTS

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Abstract:

This study examines how stakeholder perception shapes the relationship between biophilic design and sustainability outcomes in residential development. Two stakeholder groups were studied in Bahria Town, Karachi, Pakistan: developers, who decide whether biophilic features enter a project, and residents, who experience them once built. A quantitative cross-sectional survey collected data from 300 respondents (150 developers, 150 residents) using structured questionnaires on a five-point Likert scale. Because the two groups were measured with group-appropriate indicators, two separate partial least squares structural equation models were estimated in SmartPLS, with reliability analysis conducted in SPSS. Biophilic design significantly influenced stakeholder perception in both groups, and perception in turn significantly influenced sustainability outcomes. The resident model showed partial mediation: the direct effect of biophilic design on sustainability outcomes remained significant alongside the indirect effect. The developer model showed full mediation, with no statistically reliable direct pathway once perception was accounted for. Between-group comparisons are descriptive rather than inferential, since no formal statistical test of group difference was conducted and the two instruments use different indicators. Within that limitation, the developer model produced larger coefficients and explained more variance, but its discriminant validity was not established, with two of three construct pairs exceeding the conservative threshold; the resident model's more modest effects rest on a fully validated measurement model and are the better supported of the two. The findings show that

design provision alone does not deliver sustainability outcomes, and that stakeholder perception is the pathway through which it does.

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Keywords:

Biophilic Design; Residential Development; Stakeholder Perception; Sustainability; Sustainable Housing



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Introduction

Urbanization and population growth has increased the demand for housing all over the world at an unprecedented speed, leading to challenges in sustainable urban development. The growth of cities and urbanisation is accompanied by the degradation of natural environments, the loss of biodiversity, environmental deterioration and the reduction of access to green spaces, among other things, which negatively affects human well-being. UN-Habitat (2022) forecasts that by 2050, the global population will be living in cities, under significant pressure from housing infrastructure and an urban ecosystem. By viewing cities as complex ecological and social systems, instead of single built structures (Newman & Jennings, 2022), the use of housing-level interventions, like biophilic design, can help illustrate how these interventions can have impacts that rise above the level of individual units to the wider scope of city sustainability and public-health outcomes, such as the type of climate adaptation public health co-benefits Sharifi et al. (2021) documented. Thus, sustainable housing solutions which combine environmental, social and economic goals are emerging as a major policy, development and urban planning and research issue.

Sustainable housing development aims to create residential environments that reduce environmental impact while increasing social benefit and economic viability. Traditional strategies have concentrated on energy efficiency, resource conservation and environmental performance, but recent work shows that sustainability extends beyond technical concerns to human health, psychological well-being and quality of life. Biophilic design has emerged in this context as an approach that incorporates natural materials and experiences into the built environment to strengthen human–nature connections and support sustainable development goals.

Biophilic design is based on the Biophilia Hypothesis of Wilson (1984), which states that humans have an innate attraction to nature and living systems. Biophilic Design in Architecture and Urban Design is the inclusion of greenery, views of nature, water elements, natural materials, green infrastructure, and natural light in built-up spaces. The benefits of biophilic design for environmental sustainability, occupant health, psychological restoration, productivity and life satisfaction have been demonstrated in previous studies (Kellert, 2018; Browning et al., 2014; Ryan et al., 2014). In homes, biophilic design is associated with improved indoor environmental quality, increased social interaction, reduced stress, and increased satisfaction among residents.

Despite growing recognition of biophilic design as a sustainable approach, its implementation in housing developments remains inconsistent, particularly in developing countries, where priorities and perceptions differ across key stakeholders. Two groups are most influential: developers, who focus on feasibility, profitability, market competitiveness and regulatory compliance, and residents, whose concerns centre on housing quality, environmental comfort, health and well-being (Freeman, 1984; Hörisch et al., 2014). These divergent perspectives shape how biophilic principles are applied and realised.

Studies that consider biophilic design in combination with stakeholder perceptions and sustainability benefits in residential development in developing countries are scarce in the empirical literature. With the exception of comparatively little work in the context of residential communities in emerging urban contexts like Pakistan, the literature has focused primarily on commercial buildings, healthcare, and educational institutions (Gillis & Gatersleben, 2015; Mangone et al., 2022). With urbanization in Pakistani cities rapidly expanding and increased demand for sustainable housing, it is important and timely to understand the perceptions of stakeholders towards biophilic design.

To fill these shortcomings, the present study focuses on the impact of biophilic design on sustainability outcomes with the perspective of the developers and residents of Bahria Town, Karachi, which is one of the biggest planned residential communities in Pakistan. The study proposes two independent models of PLS-SEM, one for each stakeholder group, analyses (a) the direct impact of biophilic design on both stakeholder and sustainability, and (b) the mediating effect of stakeholder between biophilic design and sustainability outcomes for both groups. More specifically, the study is based on two theories: the Stakeholder Theory and the Attention Restoration Theory, and, in a residential context in a developing country, provides empirical evidence of the strategic importance of biophilic design in sustainable urban housing.

Literature Review

Sustainable Housing Development

Sustainable housing development has become a central concern of contemporary urban planning as environmental awareness rises and cities face the combined pressures of rapid urbanisation, climate change and the depletion of natural resources. Sustainable housing is not simply the provision of shelter; it is housing that is environmentally responsible, economically efficient and socially healthy. The United Nations Sustainable Development Goals link sustainable housing directly to inclusive, safe, resilient and sustainable communities (United Nations, 2015). Sustainable residential environments are therefore expected to carry a minimal environmental footprint while improving occupants' quality of life and supporting long-term social and economic stability.

The issue carries particular weight in developing countries, where rapid urban growth places acute strain on infrastructure, natural resources and environmental systems. Pakistan has seen substantial urban population growth over the past two decades, accompanied by strong demand for housing that meets environmental, social and economic requirements (Xue et al., 2023). In practice, however, many housing projects remain driven principally by economic considerations, with limited attention to environmental performance or human-centred design. This gap between what sustainable housing is expected to deliver and what is actually built points to a need for design approaches that address environmental and human outcomes together.

Sustainability in housing, then, is not achieved by technical specification alone. Environmentally responsive design strategies deliver their intended benefits only when the actors who commission, build and inhabit residential environments recognise those benefits and act on them. How such strategies are perceived and valued by stakeholders is therefore part of the sustainability question, not separate from it.

Biophilic Design As An Approach To Sustainable Housing

Biophilic design incorporates natural elements, patterns and processes into the built environment to strengthen the connection between people and nature. The approach rests on Wilson's (1984) Biophilia Hypothesis, which holds that people have an innate tendency to seek connection with nature and living systems, and that this connection is a source of psychological, emotional and physical health. Kellert (2018) defines it as the intentional use of nature within the built environment to improve human health, productivity and environmental performance, while Browning et al. (2014) set out the widely cited "14 Patterns of Biophilic Design", grouping biophilic experience into nature in the space (direct experience of plants, water, airflow and daylight), natural analogues (materials, textures and patterns) and nature of the space (spatial experiences such as prospect, refuge and mystery). Recent work supports the benefits of biophilic environments for mental health, stress reduction, cognitive functioning and satisfaction with the built environment (Ryan et al., 2014; Mangone et al., 2022; Beatley & Newman, 2023).

Classifying biophilic patterns does not by itself explain why biophilic design should be treated as a sustainability strategy rather than an aesthetic preference. Its relevance rests on a contribution that runs across all three conventional sustainability dimensions (Elkington, 1997) rather than being confined to one. **Environmentally**, vegetation, tree cover, water features and green infrastructure moderate microclimate and support thermal comfort, while daylight access and natural ventilation reduce reliance on mechanical systems; read as ecosystem services delivered at housing scale (Zari, 2018; Zari & Hecht, 2024), these carry biodiversity and climate-adaptation co-benefits beyond the individual plot (Newman & Jennings, 2022; Sharifi et al., 2021). **Socially**, contact with greenery, daylight and ventilation supports psychological restoration, environmental comfort and perceived residential quality, shaping how residents evaluate where they live (Gillis & Gatersleben, 2015; Xue et al., 2023). **Economically**, biophilic features carry implications for project attractiveness, market positioning and longer-term value, differentiating a development in a competitive market and influencing willingness to pay (Ortega et al., 2024), which brings biophilic design into investment appraisal rather than design preference alone.

Biophilic design therefore connects environmental performance, human experience and development viability at once. That breadth is also the source of the problem this study addresses: an approach whose value is environmental, experiential and commercial simultaneously will be assessed differently depending on who is assessing it, and will only be implemented if those controlling implementation judge it worthwhile. Stakeholder perception is therefore a necessary object of study, not a secondary one.

Stakeholders in Sustainable and Biophilic Housing Development

Housing development is a multi-actor process in which design intent is negotiated and realised through the decisions of several parties, none of whom controls the outcome alone. Developers commission and finance projects and set the parameters within which design operates; architects and landscape designers translate those parameters into spatial proposals; planners and regulatory authorities set the rules projects must satisfy; contractors determine what is built in practice; and residents occupy the result, influencing through use, maintenance and preference how it performs over time and what is built next. Each holds distinct interests and each effect both implementation and the sustainability of the outcome.

Two of these groups occupy positions that make them particularly consequential for biophilic design specifically. Developers control whether biophilic features enter a project at all: they hold the budget, set the specification and carry the commercial risk, and their assessment of biophilic design is accordingly filtered through feasibility, economic viability, regulatory requirement, marketability and development performance. Residents, by contrast, determine whether biophilic features deliver anything once built. They encounter biophilic design through everyday experience — environmental comfort, housing quality, health and well-being — and it is their sustained use and valuation that converts design provision into sustainability outcome. The literature suggests that the priorities of these two groups may not align, with delivery-side actors weighting commercial and regulatory considerations and occupants weighting experiential and health-related ones (Freeman, 1984; Hörisch et al., 2014; Kujala et al., 2022). Where such a divergence exists, it has direct consequences for how biophilic principles are specified, built and maintained in residential developments. Examining both groups is therefore not a matter of sampling breadth but of capturing the two positions in the delivery chain where biophilic design is decided and where it is realised.

Theoretical Underpinning

This study draws on two theories that answer different questions about the same relationship. Stakeholder Theory addresses who assess biophilic design and why their assessments differ; Attention Restoration Theory addresses the mechanism through which biophilic environments produce the experiential benefits that at least one of those groups is assessing. Neither theory is sufficient alone, and they are presented here as a single theoretical foundation rather than as two separate reviews.

Stakeholder Theory

Stakeholder Theory, introduced by Freeman (1984), holds that an organisation's decisions should account for the interests and expectations of all parties affected by its activity, not shareholders alone. Applied to housing development, it directs attention to the multiple actors identified in Section 2.3 and to the proposition that project outcomes reflect the interaction of their differing priorities.

This study requires the theory for a specific reason. Biophilic design has no automatic route from principle to implementation: it enters a project only if the party controlling specification judges it worthwhile, and it delivers value only if the party occupying the result recognises and sustains that value. Stakeholder Theory supplies the argument for treating perception as a variable in its own right rather than an attitudinal by-product, and the expectation that the two groups will evaluate the same physical features against different criteria — the basis for modelling them separately rather than pooling them.

Contemporary stakeholder research supports this emphasis. Hörisch et al. (2014) show that stakeholder involvement contributes to environmental performance, organisational legitimacy and sustainability success, and Kujala et al. (2022) argue that stakeholder perceptions are decisive for the implementation of sustainable development strategies. Within construction and property specifically, stakeholder configurations have been shown to shape project risk and sustainability performance (Yang et al., 2016; Qureshi et al., 2021).

Attention Restoration Theory

Attention Restoration Theory (Kaplan & Kaplan, 1989) offers a psychological account of why contact with nature benefits human well-being. It proposes that natural settings possess four restorative properties — fascination, being away, extent and compatibility — which replenish cognitive resources, reduce mental fatigue and restore attentional capacity. Evidence consistently supports the link between nature exposure and attention restoration and cognitive functioning (Ohly et al., 2016), and between contact with nature and psychological health, emotional stability and mental recovery (Stevenson et al., 2018).

Biophilic design brings these conditions into the built environment, making the restorative experience available in everyday residential settings rather than requiring travel to natural ones. In residential developments, the resulting benefits can be linked to higher satisfaction, greater environmental awareness and stronger support for sustainability measures. ART thus specifies the mechanism by which the physical presence of biophilic features becomes an experienced benefit capable of shaping how residents evaluate their housing.

The Two Theories as Complementary Foundations

The two theories are complementary rather than interchangeable. Stakeholder Theory explains the structure of the problem — that biophilic design is assessed by different actors, from different positions, against different criteria, and that these assessments determine whether sustainability outcomes follow. Attention Restoration Theory explains the mechanism on one side of that structure: the restorative process through which biophilic environments generate the benefits residents perceive.

Read together, they support a single proposition. Biophilic features produce experiential and instrumental value (ART supplying the mechanism for the former), stakeholders perceive that value from their respective positions (Stakeholder Theory supplying the account of why those positions differ), and it is the perception, rather than the physical provision alone, that carries through to sustainability outcomes. This is the pathway the present study models.

Biophilic Design, Stakeholder Perception and Sustainability Outcomes

The preceding sections establish that biophilic design contributes across sustainability dimensions, that its implementation and realisation depend on two distinct stakeholder groups, and that theory supports treating perception as the link between them. This section develops the three relationships that follow from that argument and that together constitute the conceptual model.

Biophilic Design and Stakeholder Perceptions

Stakeholder perception refers to the beliefs, attitudes, evaluations and interpretations that stakeholders hold about a project, policy or initiative, and it shapes decision-making, behavioural intention, acceptance and support for sustainability-related practice (Kujala et al., 2022).

There is reason to expect biophilic design to influence these perceptions in both groups, though by different routes. For residents, the route is experiential and is specified by ART: sustained exposure to greenery, daylight, natural ventilation and views of nature produces restorative benefit, and that benefit is registered as a more favourable assessment of environmental comfort, housing quality and residential well-being (Kaplan & Kaplan, 1989; Gillis & Gatersleben, 2015; Xue et al., 2023). Perception here is formed through daily use rather than through evaluation of a proposition.

For developers, the route is evaluative and is specified by Stakeholder Theory. Developers assess biophilic features against project criteria differentiation in a competitive market, resident demand, regulatory positioning and long-term asset value and where those features are judged to strengthen the project on those criteria, they are perceived favourably (Beatley & Newman, 2023; Ortega et al., 2024; Qureshi et al., 2021). The same physical provision is thus processed through two different evaluative frames, which supports separate modelling of the two groups.

Stakeholder Perceptions and Sustainability Outcomes

Perception matters for sustainability outcomes because it precedes the behaviour that produces them. Stakeholder perceptions have been shown to influence sustainability outcomes through behavioural support, environmental responsibility and long-term engagement (Hörisch et al., 2014).

The behavioural pathway differs by group. Developers who perceive biophilic design as valuable can act on that perception through the decisions they control specification, investment, retention of green space against competing land uses, and continued provision in later phases. Residents who perceive their environment favourably are more likely to conserve resources, participate in community stewardship and support environmental initiatives, and as continuous occupants they exert a sustained rather than episodic influence (Gillis & Gatersleben, 2015; Mangone et al., 2022). Perception translates into outcomes through supply-side decisions for one group and through use and maintenance for the other.

In both cases the same logic holds physical provision creates the possibility of sustainability benefit, and perception determines whether that possibility is acted upon.

The Mediating Role of Stakeholder Perceptions

Taken together, these two relationships yield a mediated pathway rather than two independent ones. Biophilic design shapes how stakeholders perceive a residential environment, and those perceptions shape the decisions and behaviours through which sustainability outcomes are realised. Modelling perception as a mediator test whether the connection runs through perception or operates independently of it.

A direct pathway from biophilic design to sustainability outcomes may also persist alongside the mediated one, since some environmental functions of vegetation and green infrastructure operate irrespective of whether anyone perceives them favourably (Zari & Hecht, 2024). Whether mediation is partial or full is therefore an empirical question, and one that may resolve differently for a group whose relationship to the environment is experiential than for a group whose relationship to it is evaluative and commercial. The present study examines this for developers and residents separately.

Synthesis, Research Gaps and Conceptual Framework

Synthesis And Research Gaps

The literature reviewed above establishes three things: biophilic design has a plausible contribution to make across the environmental, social and economic dimensions of sustainable housing; that contribution depends on two stakeholder groups occupying different positions in the delivery chain; and theory supports treating stakeholder perception as the pathway linking design provision to sustainability outcome. Together these identify three gaps.

Contextual gap. Empirical evidence on biophilic design in residential development in developing-country contexts remains limited. The literature has concentrated on commercial, healthcare and educational buildings, predominantly in developed countries (Gillis & Gatersleben, 2015; Mangone et al., 2022), leaving planned residential communities in rapidly urbanising economies such as Pakistan comparatively unexamined. Earlier work in this setting established stakeholder support for biophilic principles alongside institutional, economic and technical barriers to adoption (Anwar et al., 2026), but did not model the pathway from design provision through perception to sustainability outcomes, nor separate the delivery side from the experiencing side.

Stakeholder gap. Biophilic design research has focused principally on occupants and users, and on health or environmental benefits, with less comparative attention to those who deliver housing. The delivery side and the experiencing side have rarely been examined alongside one another in a single study, despite implementation depending on the former and realisation on the latter.

Theoretical gap. Few studies simultaneously examine the full pathway connecting biophilic design, stakeholder perceptions and sustainability outcomes, and fewer still across distinct stakeholder groups. The mediating role of perception in this pathway, and whether it operates equivalently for different stakeholder positions, remains largely untested.

Conceptual Framework

Addressing these gaps requires a framework in which biophilic design, stakeholder perception and sustainability outcomes are modelled together, and in which the two stakeholder groups are represented separately rather than pooled. The study is accordingly grounded in Stakeholder Theory (Freeman, 1984) and Attention Restoration Theory (Kaplan & Kaplan, 1989), and two stakeholder-specific conceptual frameworks were developed, as shown in Figure 1.

Developer Model: Biophilic Design → Developer Perception → Sustainability Outcomes

Resident Model: Biophilic Design → Resident Perception → Sustainability Outcomes

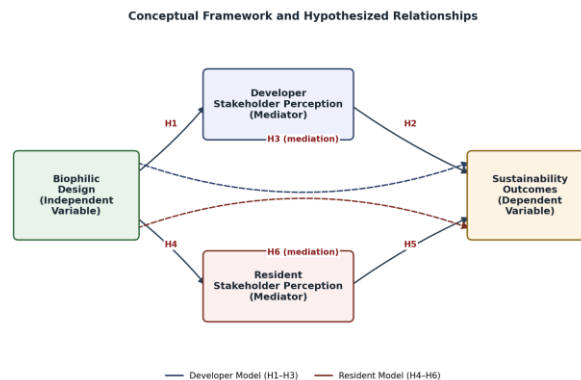


Figure 1: Conceptual Framework and Hypothesized Relationships.

In both models, biophilic design is the independent variable, sustainability outcomes the dependent variable, and stakeholder perception the mediating variable.

Research Hypotheses

The hypotheses below follow from the relationships developed in Section 2.5 and are stated separately for each stakeholder group, since the two groups evaluate biophilic design through different frames and are measured with group-appropriate indicators.

Developer Model

H1: Developers who encounter greater provision of biophilic features in residential developments will evaluate those developments more favourably in terms of project value, market competitiveness, investment attractiveness and development feasibility.

H2: The more favourably developers evaluate biophilic provision on these project criteria, the more strongly they will report environmental, social and economic sustainability benefits from residential development.

H3: Developers' evaluative perceptions transmit the influence of biophilic design on sustainability outcomes; that is, the relationship between biophilic provision and reported sustainability benefit operates through the way developers assess that provision against project criteria.

Resident Model

H4: Residents exposed to greater provision of biophilic features in their residential environment will report more favourable perceptions of environmental satisfaction, health benefit, comfort and quality of life.

H5: The more favourably residents perceive their biophilic residential environment on these experiential criteria, the more strongly they will report environmental, social and economic sustainability benefits.

H6: Residents' experiential perceptions transmit the influence of biophilic design on sustainability outcomes; that is, the relationship between biophilic provision and reported sustainability benefit operates through residents lived assessment of that provision.

Methodology

Study Context, Population and Sampling

The study was conducted in Bahria Town Karachi, one of the largest planned residential developments in Pakistan. The site was selected because it incorporates a range of biophilic and environmentally responsive design elements green spaces, parks, recreational areas, tree-lined streets and nature-oriented residential settings which makes it an appropriate context in which to examine stakeholder perceptions of biophilic design within sustainable housing development.

The target population comprised two stakeholder groups directly engaged in residential housing development at this site: (1) developers involved in planning, construction, project management and housing development activity, and (2) residents living in Bahria Town Karachi. A total sample of 300 respondents was obtained, comprising 150 developers and 150 residents. The sample size is adequate for PLS-SEM analysis and exceeds the minimum recommended by Hair et al. (2022). Allocation was equalised across the two groups in order to secure adequate statistical power for each independent model and to support descriptive cross-group comparison; it does not represent proportional representation of the underlying populations.

Developers were recruited through purposive sampling in order to include participants with relevant professional knowledge and direct experience of residential development projects within Bahria Town Karachi. Eligibility required a minimum of two years of active involvement in one or more of the following: project planning and design, construction supervision, project management, or property development and sales. Professional eligibility was established through self-reported qualifications, organisational affiliation or confirmation of role at recruitment. These credentials were not independently verified, and this is noted as a limitation.

Residents were recruited through convenience sampling on the basis of accessibility and willingness to participate. Recruitment took place across community centres, parks and residential clusters, and covered the major residential phases of Bahria Town Karachi in order to achieve wider spatial coverage.

The different sampling strategies reflect the distinct characteristics and accessibility of the two populations: purposive sampling was necessary to identify developers with the required expertise, while convenience sampling allowed broader access to residents (Saunders et al.,

2019; Sekaran & Bougie, 2020). The resulting asymmetry in recruitment rigour may introduce selection bias and limits generalisability, particularly on the resident side; it is treated as a methodological limitation in its own right, separate from the ceiling effects discussed in the Limitations section.

Demographic profiles of both groups are reported in the Findings (Tables 3 and 4).

Research Design

The study employed a quantitative research approach with a cross-sectional survey design to examine the relationships between biophilic design, stakeholder perception and sustainability outcomes in residential housing developments. A quantitative approach was appropriate because it allows relationships between variables to be measured and analysed statistically and allows the proposed hypotheses to be tested against empirical evidence (Saunders et al., 2019; Sekaran & Bougie, 2020).

A stakeholder-specific modelling approach was used, in which two separate structural models were developed and analysed for the developer and resident stakeholder groups. This approach follows from the argument developed in Section 2.3: developers' and residents' perceptions, experiences and evaluation criteria differ, and the two groups therefore require different measurement instruments and constructs (developer items: project value, market competitiveness, investment attractiveness, feasibility; resident items: environmental satisfaction, health benefits, comfort, quality of life). A standard Multi-Group Analysis (MGA) would have assumed that identical indicators were measured across the two groups, which was not the case here; two separate Partial Least Squares Structural Equation Models (PLS-SEM) were therefore estimated. It should be emphasised and is emphasised consistently throughout this paper, including in the Abstract, Discussion and Conclusion that the cross-group comparisons of path coefficients and R^2 values reported later are descriptive and interpretive rather than inferential statistical comparisons, since no formal statistical test of between-group difference (for example, a bootstrap or permutation test on a common metric) was conducted. Readers should interpret any apparent differences between the two models with corresponding caution.

Instrument Development and Measurement

Two questionnaires were used to collect data; one designed for the developers and the other for the residents. A thorough literature review of biophilic design, stakeholder perception and sustainable housing development was conducted for the development of the questionnaire. All measures were modified from those previously used, with adaptations to the residential housing setting.

The questionnaires comprised four sections. Section A collected demographic data (gender, age, education, professional experience or occupation). Section B measured biophilic design perceptions covering green spaces, natural lighting, natural ventilation, vegetation, water features and visual connections with nature. Section C assessed stakeholder perception project value, market competitiveness, investment attractiveness and development feasibility for developers; environmental satisfaction, health benefits, comfort and quality of life for residents. Section D assessed sustainability outcomes across environmental sustainability, social well-being, economic benefits and long-term residential quality. All items used a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree), as summarised in Table 1.

Table 1: Summary of Constructs, Definitions, and Item Sources

Construct	Description	Items	Scale	Source
Biophilic Design (BD)	Natural elements, analogues, and spatial configurations (Kellert's dimensions) in residential design	8–12	5-pt Likert	Kellert et al. (2008); Browning et al. (2014); Xue et al. (2023)
Stakeholder Perception (SP)	Awareness, perceived value, and acceptance of biophilic design in enhancing sustainability and living quality	5–9	5-pt Likert	Freeman (1984); Yang et al. (2018); Qureshi et al. (2021)
Sustainability Outcomes (SUS)	Perceived environmental, social, and economic benefits from biophilic design implementation in housing	6–9	5-pt Likert	Elkington (1997); Zari (2018); Zari & Hecht (2024)

Data Collection Procedure

Data were collected from the developers and residents of Bahria Town Karachi through self-administered questionnaires. A pilot study was conducted with 30 respondents (15 developers and 15 residents) to assess the clarity of the questionnaire, item understanding, reliability and face validity. Pilot data indicated good preliminary reliability (Cronbach's $\alpha > 0.70$) for all constructs, three items with ambiguous wording were reworded and one item with low variance was removed before finalization.

Participation in the main study was voluntary, and confidentiality and anonymity were preserved throughout. To minimise acquiescence bias, reverse-scored items were included for each construct. Harman's single-factor test was conducted in SPSS to check for common method bias; a single factor extracted via principal component analysis explained 28.4% of total variance, below the 50% threshold, suggesting that common method bias is unlikely to be a serious threat to the validity of the results (Podsakoff et al., 2003).

To assess non-response bias, an independent-samples t-test was conducted comparing early respondents (first 50%) and late respondents (final 50%) across all three constructs (Table 2).

Table 2: Non-Response Bias Assessment: Independent-Samples t-test (Early Vs. Late Respondents)

Construct	Early Mean (SD)	Late Mean (SD)	Mean Diff.	t-value	df	p-value
Biophilic Design	3.84 (0.62)	3.81 (0.64)	0.03	0.71	298	0.48
Stakeholder Perception	3.92 (0.58)	3.89 (0.60)	0.03	0.68	298	0.50
Sustainability Outcomes	3.88 (0.61)	3.85 (0.63)	0.03	0.74	298	0.46

There were no significant differences between early and late respondents on any of the three constructs (all $p > 0.05$), suggesting that non-response bias was not a substantial concern. The use of an independent-samples t-test is consistent with standard non-response bias assessment

procedure (Armstrong & Overton, 1977), in which early and late respondent groups are treated as independent subsamples rather than matched pairs.

Data Analysis

Data analysis was conducted using SPSS Version 26 (for descriptive statistics and reliability testing) and SmartPLS Version 4 (for PLS-SEM analysis). The measurement model was assessed for reliability and validity, and the structural model was assessed for path relationships, mediation effects, and predictive relevance. Bootstrapping with 5,000 subsamples was performed to determine the significance of all path relationships and indirect effects.

Path coefficients (β), t-values, p-values, coefficient of determination (R^2), effect sizes (f^2), and predictive relevance (Q^2) were used to evaluate the structural models. Inner variance inflation factor (VIF) values were used to screen for lateral collinearity among predictor constructs. Specific indirect effects were estimated in SmartPLS using bootstrapping to evaluate mediation.

Findings

Tables 3 and 4 summarise the demographic and background profile of the developer and resident samples. Because the groups were administered different, group-appropriate questionnaires, the background variables differ: developers were profiled on professional experience, organisational role and design-decision involvement, residents on standard socio-demographic characteristics.

Table 3: Developer Sample Profile (n = 150)

Characteristic	Category	n	%
Years associated with construction industry	< 5 years	60	40.0
	5–10 years	60	40.0
	10–15 years	30	20.0
Current position in organisation	CEO	35	23.3
	COO	30	20.0
	General Manager	75	50.0
	Manager	10	6.7
Involved in selecting materials/features related to:	Lighting	25	16.7
	Natural ventilation	25	16.7
	Thermal comfort	35	23.3
	None of the above	65	43.3

Table 4: Resident Sample Profile (n = 150)

Characteristic	Category	n	%
Gender	Male	75	50.0
	Female	75	50.0
Profession (based on undergraduate studies)	Architect	75	50.0
	Engineer	35	23.3
	Environmentalist	15	10.0
	Healthcare	25	16.7

Characteristic	Category	n	%
Age	Under 25 years	5	3.3
	25–35 years	40	26.7
	35–45 years	60	40.0
	45–55 years	40	26.7
	55 years and above	5	3.3
Area of early education	Urban	105	70.0
	Rural	25	16.7
	Sub-urban	20	13.3
Household income bracket	< PKR 50,000	15	10.0
	PKR 50,000–100,000	35	23.3
	PKR 100,000–200,000	40	26.7
	PKR 200,000–300,000	25	16.7
	Above PKR 300,000	35	23.3
Home tenure	Own	80	53.3
	Rent	70	46.7

The resident sample was evenly split by gender and skewed toward mid-career adults (66.7% aged 35–55), with 70.0% from urban educational backgrounds and roughly even ownership versus rental status. Notably, half the resident sample reported an architecture background by undergraduate training, which should be borne in mind when interpreting residents' biophilic design perceptions, since architecturally trained residents may evaluate design features differently from the general public (see Limitations). The developer sample was concentrated in mid-level and senior roles (General Manager 50.0%, CEO 23.3%) with substantial industry experience (80.0% with five or more years), though 43.3% reported no direct involvement in selecting the specific design features asked about.

Measurement Model Assessment

To test the structural relationships, the reliability and validity of the measurement models were examined first for developers and then for residents according to the two-stage approach suggested by Hair et al. (2022).

Reliability

The internal consistency reliability of all constructs was satisfactory. According to the results in Table 5 (Resident Model) and Table 6 (Developer Model), Cronbach's Alpha and Composite Reliability (rho_c) values for all the items in the model were above the suggested value of 0.70 for both groups of stakeholders.

Table 5: Construct Reliability And Validity — Both Models

Construct	Model	Cronbach's α	CR (rho_a)	CR (rho_c)	AVE
Biophilic Design	Resident	0.920	0.927	0.932	0.538
	Developer	0.927	0.930	0.937	0.537
Stakeholder Perception	Resident	0.831	0.844	0.880	0.557
	Developer	0.859	0.867	0.891	0.506
Sustainability Outcomes	Resident	0.877	0.883	0.907	0.619
	Developer	0.885	0.888	0.913	0.635

Thresholds: α and CR > 0.70, AVE > 0.50. All constructs meet both criteria in both models. Figures are taken directly from the SmartPLS construct reliability and validity output. Reliability and convergent validity are broadly comparable across the two models, but direct numeric comparison remains descriptive only, since the groups were measured with different indicators (see Research Design).

Convergent Validity — Outer Loadings (Resident Model)

Convergent validity was established, as all factor loadings exceeded the recommended threshold of 0.70 with the two exceptions noted below. Table 6 presents the outer loadings for the Resident Model.

Table 6: Outer Loadings — Resident Model

Item	λ	SE	t	Item	λ	SE	t
IV1	0.731	0.038	19.061	MV1	0.860	0.018	47.257
IV2	0.682	0.048	14.315	MV2	0.749	0.029	26.156
IV3	0.746	0.040	18.603	MV3	0.787	0.025	31.708
IV4	0.801	0.026	30.443	MV4	0.769	0.028	27.235
IV5	0.784	0.029	27.196	MV5	0.788	0.026	30.127
IV6	0.786	0.026	30.411	MV6	0.459	0.074	6.168
IV7	0.556	0.064	8.688	DV1	0.771	0.028	27.217
IV8	0.546	0.067	8.197	DV2	0.716	0.030	23.662
IV9	0.793	0.028	28.076	DV3	0.810	0.023	35.791
IV10	0.777	0.029	26.756	DV4	0.806	0.020	39.723
IV11	0.780	0.034	23.221	DV5	0.834	0.020	42.539
IV12	0.758	0.031	24.243	DV6	0.781	0.021	36.474

All loadings are significant at $p < 0.001$. Items IV7 ($\lambda = 0.556$, $t = 8.688$), IV8 ($\lambda = 0.546$, $t = 8.197$) and MV6 ($\lambda = 0.459$, $t = 6.168$) fall below the conventional 0.70 threshold. All three retain statistically significant loadings ($p < 0.001$) and theoretically meaningful content, and their removal did not raise AVE above threshold, so they were retained following Hair et al. (2022, p. 116). MV6 is the weakest indicator in either model and its removal should be considered in any future administration. Together with the five below-threshold items in the Developer Model, eight weak items are carried across the two instruments (see Limitations).

Discriminant Validity (Resident Model)

Heterotrait-Monotrait Ratio (HTMT) was used to determine the discriminant validity. As can be seen in Table 7, all the values of the HTMT for the Resident Model were under the recommended level of 0.85, indicating that the constructs are empirically distinct (Henseler et al., 2015).

Table 7: Discriminant Validity — Resident Model

Construct Pair	HTMT	$\sqrt{\text{AVE}}$	Correlation
Biophilic Design – Stakeholder Perception	0.753	0.733 / 0.746	0.664
Biophilic Design – Sustainability	0.704	0.733 / 0.787	0.642
Stakeholder Perception – Sustainability	0.850	0.746 / 0.787	0.731

All HTMT values fall at or below the recommended 0.85 threshold (Henseler et al., 2015), and for every pair the square root of AVE for both constructs exceeds their inter-construct correlation, satisfying the Fornell-Larcker criterion. Discriminant validity is established for the Resident Model on both criteria.

Structural Model Results: Resident Model

The Resident Model examined the effects of biophilic design on sustainability outcomes through resident stakeholder perception (Figure 2). The model explained 44.2% of the variance in stakeholder perception ($R^2 = 0.442$) and 57.8% of the variance in sustainability outcomes ($R^2 = 0.578$), indicating satisfactory explanatory power.

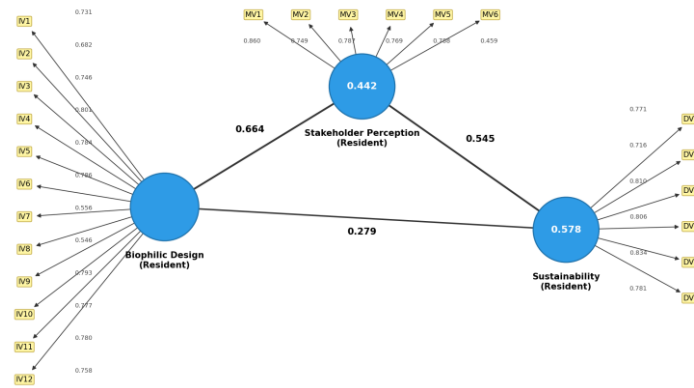


Figure 2: PLS-SEM Path Diagram — Resident Model.

Table 8: Path Coefficients and Hypothesis Testing — Resident Model

H	Relationship	β (O)	Mean (M)	STDEV	T-stat	p-value	Decision
H4	Biophilic Design → Resident Perception	0.664	0.670	0.063	10.631	0.000	Supported
H5	Resident Perception → Sustainability	0.545	0.537	0.104	5.234	0.000	Supported
—	Biophilic Design → Sustainability (Direct)	0.279	0.292	0.107	2.616	0.009	Sig.

Table 9: Specific Indirect Effect (Mediation) — Resident Model

Indirect Path	β (O)	Mean (M)	STDEV	T-stat	p-value	Decision
BD → Resident Perception → Sustainability	0.362	0.358	0.069	5.229	0.000	H6 Supported

Table 10: Total Effects — Resident Model

Relationship	β (O)	Mean (M)	STDEV	T-stat	p-value
Biophilic Design → Stakeholder Perception	0.664	0.670	0.063	10.631	0.000
Biophilic Design → Sustainability Outcomes	0.642	0.650	0.070	9.205	0.000
Stakeholder Perception → Sustainability Outcomes	0.545	0.537	0.104	5.234	0.000

H6 is supported by the specific indirect effect of Biophilic Design on Sustainability through Resident Perception ($\beta = 0.362$, $t = 5.229$, $p < 0.001$), indicating that this relationship is mediated by resident perception. The total effect of Biophilic Design on Sustainability in the Resident Model was $\beta = 0.642$ ($t = 9.205$, $p < 0.001$), and the indirect effect ($0.664 \times 0.545 = 0.362$) accounts for 56.4% of that total. The direct effect remains statistically significant alongside it ($\beta = 0.279$, $t = 2.616$, $p = 0.009$), confirming partial rather than full mediation: resident perception transmits the larger share of the influence of biophilic design on sustainability outcomes, while a distinct direct pathway persists.

Total-effect comparisons between the developer and resident models are discussed together in the Discussion, because they need to be carefully compared to one another if the comparisons are to be "like" "like" (see H2/H5 discussion below).

Model Fit (Resident Model)

The Resident Model was a good fit with the data. The Standardized Root Mean Square Residual (SRMR = 0.078) was lower than the recommended value of 0.10 (Henseler et al., 2015), which was an indication of good agreement between the model-implied and observed covariance matrices. The Normed Fit Index (NFI = 0.725) was higher than the minimum acceptable value of 0.70. The indices are consistent with the overall data structure of the resident group being represented by a mediation model with three constructs.

Table 11: Model Fit — Resident Model

Index	Saturated Model	Estimated Model	Criterion	Met?
SRMR	0.078	0.078	< 0.10	✓
NFI	0.725	0.725	> 0.70	✓
d _{ULS}	1.817	1.817	—	—
d _G	0.889	0.889	—	—
Chi-Square	674.573	674.573	—	—

Variance Explained and Predictive Relevance

The Resident Model explained 44.2% of the variance in Stakeholder Perception ($R^2 = 0.442$) and 57.8% in Sustainability Outcomes ($R^2 = 0.578$); the Developer Model explained 68.2% (R^2 adj = 0.680) and 73.4% (R^2 adj = 0.730) respectively. On the benchmarks of Hair et al. (2022), where 0.25, 0.50 and 0.75 denote weak, moderate and strong explanatory power, the Resident Model is moderate, and the Developer Model approaches strong. The larger Developer Model R^2 should be read alongside its discriminant-validity limitation, since shared variance between constructs that are not cleanly distinct can inflate R^2 for the downstream construct. Predictive relevance was assessed for both models using PLSpredict at construct level, so the values are obtained under a single procedure: Q^2 predict was 0.388 and 0.384 in the Resident Model and 0.670 and 0.591 in the Developer Model, all exceeding the 0.25 threshold. At indicator level, every one of the 14 developer indicators returned a positive Q^2 predict (range 0.192–0.524), and 12 of 14 showed a PLS-SEM RMSE below the naive linear-model benchmark (Shmueli et al., 2019). These values are summarised in Table 13.

Table 12: R² and Q² Values — Both Models

Construct	R ² (Resident)	R ² adj (Resident)	Q ² predic t (Resident)	R ² (Developer)	R ² adj (Developer)	Q ² predict (Developer)
Stakeholder Perception	0.442	—	0.388	0.682	0.680	0.670
Sustainability Outcomes	0.578	—	0.384	0.734	0.730	0.591

Q²predict values are construct-level PLSpredict results for both models and are therefore directly comparable.

Effect Sizes (f²) — Resident Model

For each of the structural paths in the Resident Model, effect sizes (f²) were calculated as $f^2 = (R^2_{\text{included}} - R^2_{\text{excluded}}) / (1 - R^2_{\text{included}})$. Biophilic design was a large predictor of resident stakeholder perception (f² = 0.789). The path from Stakeholder Perception to Sustainability Outcomes is also large (f² = 0.394), while the direct path from Biophilic Design to Sustainability is small (f² = 0.104), on the conventional Cohen (1988) thresholds used in this paper (small ≥ 0.02, medium ≥ 0.15, large ≥ 0.35). All three paths in the Resident Model are statistically and practically meaningful, with the path of Biophilic Design to Perception being the most influential single path.

Table 13: Effect Sizes (f²) — Resident Model

Path	f ²	Interpretation
BD → Stakeholder Perception	0.789	Large
BD → Sustainability (direct)	0.104	Small
SP → Sustainability	0.394	Large

Note on the Resident Model. The model reconciles fully: the total effect of Biophilic Design on Sustainability ($\beta = 0.642$) equals the direct effect ($\beta = 0.279$) plus the indirect effect ($0.664 \times 0.545 = 0.362$), and the inner VIF (1.791) corresponds to the Biophilic Design–Stakeholder Perception correlation of 0.664. Adjusted R² values were not available in the output at the time of writing and are marked accordingly.

Convergent Validity — Outer Loadings (Developer Model)

Convergent validity was established: most developer loadings exceeded 0.70, and five items were retained below threshold on the grounds applied to the Resident Model (Table 14).

Table 14: Outer Loadings — Developer Model

Item	λ	SE	t	Item	λ	SE	t
BD1	0.627	0.049	12.910	SP3	0.616	0.052	11.806
BD2	0.704	0.041	17.339	SP5	0.630	0.050	12.491
BD3	0.712	0.045	15.717	SP6	0.720	0.034	21.326
BD4	0.750	0.027	27.321	SP7	0.703	0.035	20.106
BD5	0.762	0.030	25.604	SP8	0.772	0.026	29.600
BD6	0.776	0.030	25.771	SP9	0.762	0.027	28.496
BD7	0.816	0.023	35.491	SP10	0.776	0.025	30.595
BD10	0.559	0.066	8.466	SO1	0.758	0.028	26.901
BD13	0.792	0.029	27.524	SO2	0.765	0.027	28.294

Item	λ	SE	t	Item	λ	SE	t
BD14	0.775	0.029	26.364	SO3	0.833	0.020	42.042
BD15	0.725	0.029	24.571	SO4	0.813	0.020	41.156
BD16	0.738	0.032	22.753	SO5	0.830	0.018	45.428
BD17	0.756	0.031	24.366	SO6	0.781	0.024	32.092
SP2	0.693	0.047	14.755				

All loadings are significant at $p < 0.001$. Items BD1 ($\lambda = 0.627$) and BD10 ($\lambda = 0.559$): below 0.70 but statistically significant ($p < 0.001$); retained because removal did not improve AVE (0.538) beyond threshold, and both carry theoretically meaningful content (health connection; natural textures). Items SP2 ($\lambda = 0.693$), SP3 ($\lambda = 0.616$), and SP5 ($\lambda = 0.630$): below 0.70; retained on the same criteria (SP AVE = 0.506, above the 0.50 minimum). Together with IV7, IV8 and MV6 in the Resident Model, this amounts to eight weak items across two relatively short instruments; the item pool itself — not only these individual items — is flagged for revision in future administrations (see Limitations).

Discriminant Validity (Developer Model)

Discriminant validity in the Developer Model was assessed using HTMT and the Fornell-Larcker criterion (Table 15). Confirmed bootstrap output shows this is a more substantial problem than a single borderline pair: two of the three construct pairs exceed the conservative HTMT threshold of 0.85, not one, and this limitation is stated directly rather than reasoned around.

Table 15: Discriminant Validity — Developer Model

Construct Pair	HTMT	$\sqrt{\text{AVE}}$	Correlation
Biophilic Design – Stakeholder Perception	0.913 X	0.733 / 0.711	0.826
Biophilic Design – Sustainability	0.849	0.733 / 0.797	0.777
Stakeholder Perception – Sustainability	0.956 X	0.711 / 0.797	0.845

X = exceeds the conservative HTMT threshold of 0.85.

Two construct pairs fail discriminant validity on at least one criterion. For Biophilic Design–Stakeholder Perception, HTMT (0.913) exceeds the 0.85 threshold, and the Fornell-Larcker condition also fails ($\sqrt{\text{AVE}}$ for Biophilic Design = 0.733 is less than its correlation with Stakeholder Perception, 0.826; $\sqrt{\text{AVE}}$ for Stakeholder Perception = 0.711 is also less than that correlation). For Stakeholder Perception–Sustainability, HTMT (0.956) is further above threshold still, and the Fornell-Larcker condition fails here too ($\sqrt{\text{AVE}}$ for Stakeholder Perception = 0.711 and $\sqrt{\text{AVE}}$ for Sustainability = 0.797 are both less than their correlation, 0.845). Only the Biophilic Design–Sustainability pair is (narrowly) acceptable by Fornell-Larcker, and its HTMT value (0.849) sits at the boundary of the threshold rather than comfortably below it.

This is not a minor footnote. It indicates that in the developer sample, Biophilic Design, Stakeholder Perception, and Sustainability Outcomes may not be as empirically distinct from one another as the three-construct model assumes particularly Stakeholder Perception and Sustainability, whose HTMT value (0.956) is close to indicating the same underlying construct. This materially weakens confidence in the Developer Model's structural results, including the mediation story (H1–H3): if Stakeholder Perception and Sustainability Outcomes substantially overlap, the strong path from perception to sustainability ($\beta = 0.638$) and the large total effect of biophilic design on sustainability ($\beta = 0.777$) may partly reflect shared item content and construct overlap rather than a purely substantive causal pathway. This limitation is carried

forward explicitly into the Discussion and Limitations sections rather than being explained away by conceptual proximity; the developer-side instrument should be revised — sharpening the boundary between “awareness of biophilic features,” “perceived project value,” and “perceived sustainability benefit” — before the Developer Model's path estimates are treated as fully established.

Structural Model Results: Developer Model

The Developer Model examined the influence of biophilic design on sustainability outcomes through developer stakeholder perception (Figure 3). Biophilic design exerted a strong influence on developer perception ($\beta = 0.826$, $t = 29.900$, $p < 0.001$), and developer perception in turn significantly influenced sustainability outcomes ($\beta = 0.638$, $t = 5.179$, $p < 0.001$). Unlike the Resident Model, the direct path from biophilic design to sustainability outcomes was not statistically significant ($\beta = 0.250$, $t = 1.819$, $p = 0.069$; 95% bias-corrected CI $[-0.028, 0.507]$, including zero), while the total effect ($\beta = 0.777$, $t = 15.771$, $p < 0.001$) and the specific indirect effect through perception ($\beta = 0.527$, 95% CI $[0.332, 0.735]$) were both significant. This pattern is consistent with full, indirect-only mediation, as distinct from the partial mediation observed in the Resident Model. Because Stakeholder Perception here represents professional project judgement rather than experiential assessment, these results are treated as distinct from rather than a direct analogue of the Resident Model and should be read alongside the discriminant-validity limitation noted above, since construct overlap can inflate path estimates.

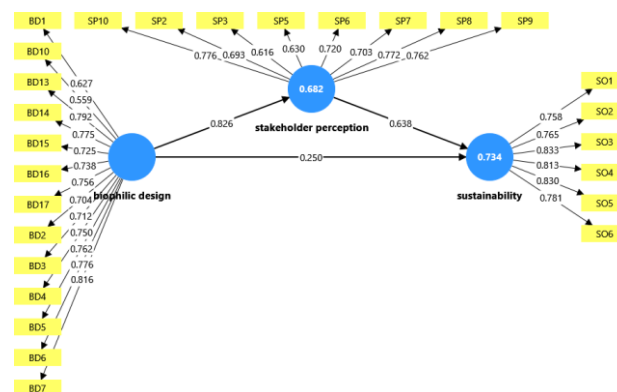


Figure 3: PLS-SEM Path Diagram — Developer Model.

Table 16: Path Coefficients and Hypothesis Testing — Developer Model

H	Relationship	β	STDEV	T-stat	p-value	95% CI (bias-corrected)	Decision
H1	Biophilic Design → Developer Perception	0.826	0.028	29.900	0.000	[0.760, 0.871]	Supported
H2	Developer Perception → Sustainability	0.638	0.123	5.179	0.000	[0.403, 0.881]	Supported
—	Biophilic Design → Sustainability (Direct)	0.250	0.137	1.819	0.069	$[-0.028,$ $0.507]$	Not significant

Bootstrap results from 5,000 subsamples. $R^2 = 0.682$ for Stakeholder Perception and 0.734 for Sustainability Outcomes. The bias-corrected confidence interval for the direct path straddles zero, corroborating the p -value; the intervals for both mediated paths exclude zero.

Table 17: Effect Sizes (f^2) — Developer Model

Path	f^2	Interpretation
BD → Stakeholder Perception	2.143	Large
BD → Sustainability (direct)	0.075	Small
SP → Sustainability	0.487	Large

Inner VIF values for the Developer Model ($BD \rightarrow SP = 1.000$; $BD \rightarrow Sustainability = 3.143$; $SP \rightarrow Sustainability = 3.143$) are all below the conservative threshold of 5, indicating collinearity is not a serious concern despite the discriminant-validity issue noted above. The corresponding Resident Model Inner VIF values ($BD \rightarrow SP = 1.000$; $BD \rightarrow Sustainability = 1.791$; $SP \rightarrow Sustainability = 1.791$) are lower still.

Table 18: Indirect Effect (Mediation) — Developer Model

Indirect Path	β	95% CI (bias-corrected)	Decision
BD → Developer Perception → Sustainability	0.527	[0.332, 0.735]	H3 Supported

Table 19: Total Effects — Developer Model

Relationship	β (O)	Mean (M)	STDEV	T-stat	p-value
Biophilic Design → Stakeholder Perception	0.826	0.831	0.028	29.900	0.000
Biophilic Design → Sustainability Outcomes	0.777	0.783	0.049	15.771	0.000
Stakeholder Perception → Sustainability Outcomes	0.638	0.636	0.123	5.179	0.000

Because the direct effect was not statistically significant ($\beta = 0.250$, $t = 1.819$, $p = 0.069$) and its bias-corrected 95% confidence interval includes zero ($[-0.028, 0.507]$), while the indirect effect was significant with an interval excluding zero ($\beta = 0.527$, $[0.332, 0.735]$), the Developer Model shows full mediation: biophilic design's influence on developer-reported sustainability outcomes runs entirely through developer stakeholder perception. The total effect ($\beta = 0.777$, $t = 15.771$, $p < 0.001$) is therefore attributable almost entirely to the mediated pathway. This should be read alongside the discriminant-validity limitation, since an inflated perception–sustainability path could partly explain why so little unique direct effect remains.

Hypothesis Summary

All six hypotheses were supported. Biophilic design is a positive predictor of stakeholder perception, and directly and indirectly of sustainability outcomes, in both stakeholder groups examined in this study. The similarities and differences between the Developer and Resident models are discussed and interpreted in the Discussion section.

Table 20: Summary of Hypothesis Testing Results

H	Relationship	Model	Decision
H1	Biophilic Design → Developer Perception ($\beta = 0.826$, $t = 29.900$, $p < 0.001$)	Developer	Supported
H2	Developer Perception → Sustainability Outcomes ($\beta = 0.638$, $t = 5.179$, $p < 0.001$)	Developer	Supported
H3	Developer Perception mediates BD → Sustainability ($\beta = 0.527$, CI [0.332, 0.735])	Developer (Full mediation)	Supported
H4	Biophilic Design → Resident Perception ($\beta = 0.664$, $t = 10.631$, $p < 0.001$)	Resident	Supported
H5	Resident Perception → Sustainability Outcomes ($\beta = 0.545$, $t = 5.234$, $p < 0.001$)	Resident	Supported
H6	Resident Perception mediates BD → Sustainability ($\beta = 0.362$, $t = 5.229$, $p < 0.001$)	Resident (Partial mediation)	Supported

The direct path BD → Sustainability Outcomes is significant in the Resident Model ($\beta = 0.279$, $t = 2.616$, $p = 0.009$) but not in the Developer Model ($\beta = 0.250$, $t = 1.819$, $p = 0.069$). This means the Resident Model shows partial mediation (a direct effect persists alongside the indirect effect) while the Developer Model shows full mediation (only the indirect, perception-mediated pathway is statistically supported). Cross-group comparisons remain descriptive; no formal inferential between-group test was conducted (see Section 3.2), and its full-mediation result should be weighed against the Developer Model's discriminant-validity limitation (Findings).

Discussion

H1 and H4: Biophilic Design and Stakeholder Perception

The results support both developers' (H1: $\beta = 0.826$, $p < 0.001$) and residents' (H4: $\beta = 0.664$, $t = 10.631$, $p < 0.001$) positive perception of biophilic design. This indicates that both stakeholder groups recognise the importance of incorporating natural elements, green infrastructure, and nature-based design into residential developments.

Developers' recognition of biophilic design as a strategic tool that enhances project attractiveness, market competitiveness and long-term value is consistent with Beatley and Newman (2023) and Kellert (2018). From a Stakeholder Theory perspective (Freeman, 1984), developers who perceive biophilic design positively are more likely to incorporate these features into planning and implementation though the Developer Model's discriminant-validity limitation means this perception construct should not yet be treated as fully distinct from awareness of the design features themselves. For residents, the positive perception is consistent with Attention Restoration Theory (Kaplan & Kaplan, 1989): regular exposure to natural light, green space, ventilation and nature views restores cognitive capacity and promotes psychological well-being, producing more positive assessments of residential quality (Ryan et al., 2014; Mangone et al., 2022).

H2 And H5: Stakeholder Perception And Sustainability Outcomes

Developer perception significantly affected sustainability outcomes (H2: $\beta = 0.638$, $t = 5.179$, $p < 0.001$), with developers holding more positive perceptions more inclined to support sustainable construction practices, environmental innovation and long-term sustainability investment. This is consistent with the stakeholder-engagement literature, which identifies engagement as a key determinant of sustainability performance (Hörisch et al., 2014).

Resident perception likewise had a significant effect (H5: $\beta = 0.545$, $t = 5.234$, $p < 0.001$). Positive resident perceptions can foster pro-ecological behaviours such as resource conservation, community environmental stewardship and support for environmental initiatives. As end users experiencing biophilic design daily, residents represent an important and consistent force for long-term sustainability outcomes (Gillis & Gatersleben, 2015).

Compared on a like-for-like basis, the Developer Model's total effect of biophilic design on sustainability outcomes ($\beta = 0.777$, $t = 15.771$, $p < 0.001$) is larger than the Resident Model's ($\beta = 0.642$, $t = 9.205$, $p < 0.001$), and the Developer Model explains substantially more variance in both mediator and outcome ($R^2 = 0.682$ and 0.734 against 0.442 and 0.578). On the numbers alone, biophilic design appears more strongly and more completely linked to sustainability outcomes for developers.

That reading requires an important qualification. The Developer Model's discriminant validity is not established: two of three HTMT ratios exceed the conservative 0.85 threshold, including 0.956 between Stakeholder Perception and Sustainability Outcomes. Where two constructs share this much variance, part of the larger R^2 and total effect may reflect item-level overlap between perceiving biophilic design positively and reporting sustainability benefit, rather than a substantively stronger relationship. The Resident Model has clean discriminant validity throughout, so its smaller but well-identified effects can be interpreted with more confidence. Readers should weigh the Developer Model's larger coefficients against its weaker measurement foundation rather than concluding that developers are simply more affected by biophilic design — and, as throughout, no formal statistical test of between-group difference was conducted, so the comparison remains descriptive.

H3 and H6: Mediating Role of Stakeholder Perception

Stakeholder perception significantly mediated the relationship between biophilic design and sustainability outcomes for both groups (H3 and H6 both supported), but when significant is examined appropriately there is a different type of mediation in the two models. In the Resident Model, the specific indirect effect ($\beta = 0.362$, $t = 5.229$, $p < 0.001$) was significant and the direct effect ($\beta = 0.279$, $t = 2.616$, $p = 0.009$) remained alongside it indicating partial mediation, with stakeholder perception explaining roughly 56% of the total effect while a genuine direct pathway from biophilic design to sustainability outcomes persists. In the Developer Model, the specific indirect effect ($\beta = 0.527$, 95% bias-corrected CI [0.332, 0.735], excluding zero) was significant, but the direct effect ($\beta = 0.250$, $t = 1.819$, $p = 0.069$) was not indicating full (indirect-only) mediation: essentially all of biophilic design's estimated influence on developer-reported sustainability outcomes runs through developer stakeholder perception, with no statistically reliable direct pathway once perception is accounted for.

The developer full-mediation result must again be read alongside the discriminant-validity concern: where mediator and outcome are not cleanly separated by the measurement model, an apparently complete mediated pathway is also what weak discriminant validity would tend to produce. Both models support the central claim that stakeholder perception is a critical pathway linking biophilic design to sustainability outcomes, but the resident result can be taken at face value while the developer result is best treated as suggestive pending a revised instrument (see Limitations).

Comparative Interpretation Of Stakeholder Models

Beyond the path coefficients, the two models differ in three respects. On measurement quality they are broadly comparable in reliability and convergent validity (Table 5), the clear exception being discriminant validity: fully established for the Resident Model, violated for two of three construct pairs in the Developer Model. This is a genuine asymmetry, and it means the Developer Model's H1–H3 findings carry substantially more measurement-level uncertainty than the Resident Model's H4–H6 findings. On sampling, the gap in recruitment rigour between purposively screened developers and conveniently sampled residents is a limitation in its own right. On the practical reading, the Developer Model shows larger total effects, larger R^2 values and full rather than partial mediation, but its measurement model does not cleanly separate perception from outcomes, so these numbers are best treated as an upper-bound, exploratory estimate; the Resident Model's smaller, partially mediated effects are the more measurement-secure finding. Practically, this suggests prioritising the Resident Model's results when making confident claims to practitioners, while treating the Developer Model's as a promising but provisional signal warranting confirmation with a revised instrument. Both models support the paper's core contribution: stakeholder perception mediates the relationship between biophilic design and sustainability outcomes for both groups examined.

Theoretical And Practical Contributions

Theoretically, this research contributes to the integration of Stakeholder Theory and Attention Restoration Theory in sustainable residential housing research from a developing-country perspective. Most biophilic design research has been conducted in developed countries and in non-residential building types (Gillis & Gatersleben, 2015); this study contributes empirical evidence from a residential community in Pakistan, addressing both a geographical and a typological gap.

Practically, the results carry implications for architects, developers, planners and policymakers. Biophilic elements green space, natural ventilation, daylight access and vegetation should be systematically incorporated into residential project specifications; developers should be made aware of the long-term economic and market benefits of biophilic features, while the developer-side survey instrument is revised to sharpen the boundary between awareness and perceived value; and resident-engagement mechanisms should be built into project design to capitalise on the sustainability pathway already evident among end users.

Conclusion

This study examined the effect of biophilic design on sustainability outcomes, with stakeholder perception as mediator, in two separate models for developers and residents of Bahria Town Karachi. All six hypotheses were supported: biophilic design positively affects stakeholder perception (H1, H4); perception positively affects sustainability outcomes (H2, H5); and perception mediates the relationship between the two in both groups (H3, H6).

The Developer Model produced numerically larger effects throughout greater variance explained ($R^2 = 0.682$ and 0.734 against 0.442 and 0.578), a larger total effect of biophilic design on sustainability ($\beta = 0.777$ against 0.642), and full rather than partial mediation, its direct effect being non-significant ($\beta = 0.250$, $p = 0.069$) where the resident direct effect remained significant ($\beta = 0.279$, $p = 0.009$). Taken at face value this would suggest biophilic design is more strongly and more completely linked to sustainability outcomes for developers. That reading must be qualified by measurement quality. Discriminant validity was fully established for the Resident Model but violated for two of three construct pairs in the Developer

Model, most notably between Stakeholder Perception and Sustainability Outcomes (HTMT = 0.956). The Developer Model's larger effects may therefore be inflated by insufficient separation between its perception and outcome measures. The more defensible conclusion is two-part: biophilic design matters for sustainability outcomes in both groups, and the Resident Model's more modest, partially mediated results are the better supported of the two, while the Developer Model's larger, fully mediated results are a promising but provisional signal awaiting confirmation with a revised instrument. Both models met standard reliability and convergent-validity thresholds (Cronbach's $\alpha > 0.83$; AVE > 0.50), and inner VIF values (1.000–3.143) rule out multicollinearity as an alternative explanation.

The findings show that design provision alone does not deliver sustainability outcomes; stakeholder perception is the pathway through which it does. Future replication in other Pakistani cities, longitudinal designs, and attention to boundary conditions such as socioeconomic status and regulatory environment would strengthen the generalisability of these findings.

Limitations And Future Research

Several limitations should be borne in mind. The cross-sectional design captures stakeholder perceptions at a single point in time and does not support causal inference; longitudinal work would show how those perceptions evolve.

The study setting is itself a limitation. Bahria Town Karachi is a well-resourced planned community with established green spaces, parks and tree-lined avenues, so respondents were evaluating an environment in which biophilic design is already normalised rather than a prospective intervention. This may produce ceiling effects in perception scores and limits generalisability to lower-resource or more densely urbanised settings. Separately, the two groups were recruited using methods of different rigour developers through purposive sampling with a professional-experience screen, residents through convenience sampling at community locations which may introduce selection bias, particularly on the resident side. Developer eligibility rested on self-reported role and credentials rather than third-party attestation.

At the measurement level, eight items fell below the 0.70 loading threshold: IV7 (0.556), IV8 (0.546) and MV6 (0.459) in the Resident Model, and BD1, BD10, SP2, SP3 and SP5 in the Developer Model. All were retained because they were statistically significant, theoretically relevant, and their removal did not improve AVE. MV6 warrants particular attention: at 0.459 it is the weakest indicator in either model or the only Stakeholder Perception item addressing maintenance cost rather than lived experience, which may explain its poor fit. Eight weak items across two relatively short instruments suggest that the item pools themselves, not merely these individual items, warrant revision.

More substantively, discriminant validity was not established in the Developer Model. Two of three construct pairs exceed the conservative HTMT threshold of 0.85 Biophilic Design Stakeholder Perception (0.913) and, more strikingly, Stakeholder Perception Sustainability (0.956) and the Fornell-Larcker criterion is violated for both. These constructs may not be empirically distinct among developers, which weakens confidence in the Developer Model's structural and mediation results (H1–H3) and raises the possibility that its larger R^2 and total effect are inflated by construct overlap. The developer-side instrument should be revised before those path estimates are treated as established.

Inner VIF values in both models (Resident 1.000–1.791; Developer 1.000–3.143) remain below the conservative threshold of 5, so multicollinearity is not an alternative explanation. Predictive relevance was assessed for both models using PLSpredict at construct level; blindfolding-based Q^2 was not computed for either, or reporting both procedures would allow the assessment to be triangulated in future work. Common method bias, a known risk in single-source self-report surveys, was assessed with Harman's single-factor test (variance extracted = 28.4%) and partially mitigated through procedural measures but cannot be ruled out; marker-variable or multi-informant designs would address it more directly.

Two sample-composition issues are raised by the demographic profile (Tables 3 and 4). Half of the resident sample (50.0%) reported an architecture background, meaning "resident" perceptions are not drawn from a general public sample; this may inflate the sophistication or positivity of resident perception scores relative to a lay population. Separately, 43.3% of the developer sample reported no direct involvement in selecting the specific design features the questionnaire asked about, so a substantial minority of developer responses reflect general organisational perception rather than first-hand design-decision experience. Neither is modelled here, and both are candidate moderators.

Finally, cross-group comparisons of path coefficients and R^2 throughout this paper are descriptive rather than inferential, owing to the non-equivalence of construct indicators and the absence of a formal statistical test of between-group difference.

Future research should extend the framework across more diverse residential contexts and stakeholder groups, including architects, planners and policymakers, and examine the moderating effects of demographic variables such as income, education, tenure, professional background and level of involvement in design decisions. Establishing theoretically equivalent indicators across groups would permit a formal multi-group and measurement-invariance approach, providing a stronger basis for testing differences in stakeholder perceptions and their relationships with sustainable housing outcomes.

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References

- Anwar, Q., Wan Ismail, W. A., Abdullah, S., & Aftab, T. (2026). Biophilic urbanism in developing regions: A sustainability framework for Bahria Town, Karachi. *Journal of Tourism, Hospitality and Environment Management*, 11(43), 337–349. <https://doi.org/10.35631/JTHEM.1143021>
- Armstrong, J. S., & Overton, T. S. (1977). Estimating nonresponse bias in mail surveys. *Journal of Marketing Research*, 14(3), 396–402.
- Beatley, T., & Newman, P. (2023). *Biophilic cities and health: Creating urban environments that support human wellbeing*. Springer.
- Browning, W. D., Ryan, C. O., & Clancy, J. O. (2014). 14 patterns of biophilic design: Improving health and well-being in the built environment. Terrapin Bright Green.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.
- Elkington, J. (1997). *Cannibals with forks: The triple bottom line of 21st century business*. Capstone.
- Freeman, R. E. (1984). *Strategic management: A stakeholder approach*. Pitman.
- Gillis, K., & Gatersleben, B. (2015). A review of psychological literature on the health and wellbeing benefits of biophilic design. *Buildings*, 5(3), 948–963.
- Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2022). *A primer on partial least squares structural equation modeling (PLS-SEM)* (3rd ed.). Sage.
- Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, 43(1), 115–135.
- Hörisch, J., Freeman, R. E., & Schaltegger, S. (2014). Applying stakeholder theory in sustainability management: Links, similarities, dissimilarities, and a conceptual framework. *Organization & Environment*, 27(4), 328–346.
- Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. Cambridge University Press.
- Kellert, S. R. (2018). *Nature by design: The practice of biophilic design*. Yale University Press.
- Kellert, S. R., Heerwagen, J. H., & Mador, M. L. (2008). *Biophilic design: The theory, science and practice of bringing buildings to life*. Wiley.
- Kujala, J., Sachs, S., Leinonen, H., Heikkinen, A., & Laude, D. (2022). Stakeholder engagement: Past, present, and future. *Business & Society*, 61(5), 1136–1196.
- Mangone, G., Mylonas, Y., & Nikolopoulou, M. (2022). Resident preferences for nature-inclusive housing developments: A cross-sectional survey. *Urban Climate*, 41, 101064.
- Newman, P., & Jennings, I. (2022). *Cities as sustainable ecosystems: Principles and practices*. Island Press.
- Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention restoration theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B*, 19(7), 305–343.
- Ortega, R., Casals, M., & Gangolells, M. (2024). Biophilic design preferences in residential settings: Empirical evidence from multi-family housing. *Sustainable Cities and Society*, 99, 104985.
- Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, 88(5), 879–903.

- Qureshi, M. I., Khan, N., Qayyum, S., Malik, S., & Sanil, H. S. (2021). Classifications of sustainable development goals (SDGs) for the construction industry and their impact on sustainable construction projects. *Energies*, 14(15), 4558.
- Ryan, C. O., Browning, W. D., Clancy, J. O., Andrews, S. L., & Kallianpurkar, N. B. (2014). Biophilic design patterns: Emerging nature-based parameters for health and well-being in the built environment. *Archnet-IJAR: International Journal of Architectural Research*, 8(2), 62–76.
- Saunders, M., Lewis, P., & Thornhill, A. (2019). *Research methods for business students* (8th ed.). Pearson Education.
- Sekaran, U., & Bougie, R. (2020). *Research methods for business: A skill-building approach* (8th ed.). Wiley.
- Sharifi, A., Pathak, M., Joshi, C., & He, B. J. (2021). A systematic review of the health co-benefits of urban climate change adaptation. *Science of the Total Environment*, 754, 141929.
- Shmueli, G., Sarstedt, M., Hair, J. F., Cheah, J. H., Ting, H., Vaithilingam, S., & Ringle, C. M. (2019). Predictive model assessment in PLS-SEM: Guidelines for using PLSpredict. *European Journal of Marketing*, 53(11), 2322–2347.
- Stevenson, M. P., Schilhab, T., & Bentsen, P. (2018). Attention restoration theory II: A systematic review to clarify attention processes affected by exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B*, 21(4), 227–268.
- UN-Habitat. (2022). *World cities report 2022: Envisaging the future of cities*. United Nations Human Settlements Programme.
- United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development*. United Nations.
- Wilson, E. O. (1984). *Biophilia: The human bond with other species*. Harvard University Press.
- Xue, F., Gou, Z., Lau, S. S. Y., Chung, K. L., & Zhang, J. (2023). Biophilic design in the residential environment: Residents' perceptions and well-being outcomes. *Building and Environment*, 227, 109773.
- Yang, R. J., Zou, P. X. W., & Wang, J. (2016). Modelling stakeholder-associated risk networks in green building projects. *International Journal of Project Management*, 34(1), 66–81.
- Zari, M. P. (2018). Ecosystem services analysis for the design of regenerative urban built environments. *Buildings and Cities*, 9(1), 1–20.
- Zari, M. P., & Hecht, K. (2024). Biophilic urbanism and ecosystem services: Toward integrated sustainability assessment. *Sustainability Science*, 19, 123–141.