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Business and Cultural Influences on Sustainability in 3D Design Modeling

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Abstract
There is an increasing focus on sustainability in the global three-dimensional (3D) design modeling industry. Businesses are encouraged to prioritize profitability and integrate sustainable practices into their 3D models. However, customer preferences for sustainable designs may vary due to cultural influences, which can impact the effectiveness of marketing strategies. This study aims to explore the influence of cultural values on the adoption and perception of sustainability in 3D design modeling. A pretest was conducted to ensure the reliability and validity of the questionnaire. The collected data were analyzed using satisfaction levels, confirmatory factor analysis, and structural equation modeling to assess the impact of cultural dimensions on sustainable 3D design preferences. The results revealed that specific cultural dimensions, such as uncertainty avoidance and long-term orientation, significantly shape customer preferences for sustainable 3D designs. Additionally, eco-friendly design features and product longevity emerged as critical factors influencing customer satisfaction in different cultural contexts. The insights gained from this study provide valuable guidance for businesses and policymakers in aligning 3D design practices with consumer preferences for sustainability. These findings can help organizations develop products that meet sustainability goals while appealing to culturally diverse markets. This research offers essential information for designers and businesses to create 3D design models that incorporate sustainable elements to consumer preferences across various cultural contexts.
Keywords: Sustainability, 3D Design, Business Practices, Cultural Influences

Introduction

Sustainability is growing across various sectors, making it essential to embed sustainable practices in three-dimensional (3D) design modeling (Ali et al., 2024). This concept also involves addressing the environmental effects and considering the business and cultural aspects (Verma & Singh, 2024). Companies increasingly focus on integrating sustainability into their design processes to enhance performance and lessen environmental impact. This includes examining how design choices affect resource consumption, waste production, and ecological consequences (Dixit et al., 2023). Cultural influences are crucial in sustainable 3D design (Espina-Romero et al., 2023). Cultures have unique attitudes and practices related to sustainability, which can influence both design approaches and the implementation of sustainable technologies (Turner & Oyekan, 2023). For example, cultural priorities regarding environmental practices vary based on local traditions and values (Wang, 2023). Recognizing these cultural influences is vital for developing 3D models that are both effective and aligned with cultural norms (Akbarieh et al., 2020). Balancing business objectives with cultural considerations to meet sustainability targets poses a challenge. Companies must address the complexities of integrating cultural values into their design practices while achieving sustainability goals (Gopalkrishnan, 2019). This involves understanding how cultural values shape design preferences and aligning these with sustainable practices (Narayanan et al., 2020).

To overcome these challenges, frameworks, and guidelines that merge business and cultural perspectives in 3D design modeling have been proposed. This strategy aims to create designs that fulfill sustainability requirements while also being culturally (Cope et al., 2022). Such approaches contribute to more comprehensive and effective sustainability practices in 3D design.

Although there have been improvements in incorporating sustainability into 3D design, further research is needed to explore the interplay of cultural and business factors and their impact on sustainability outcomes (Zhang et al., 2020). Investigating these aspects can provide valuable insights into developing design solutions that are environmentally friendly and culturally sensitive (Gopalkrishnan, 2019). Therefore, addressing these issues will help refine 3D design practices and support broader sustainability objectives in the industry (Lascu et al., 2021). An overview of 3D design practice and business sustainability can be shown in Figure 1.

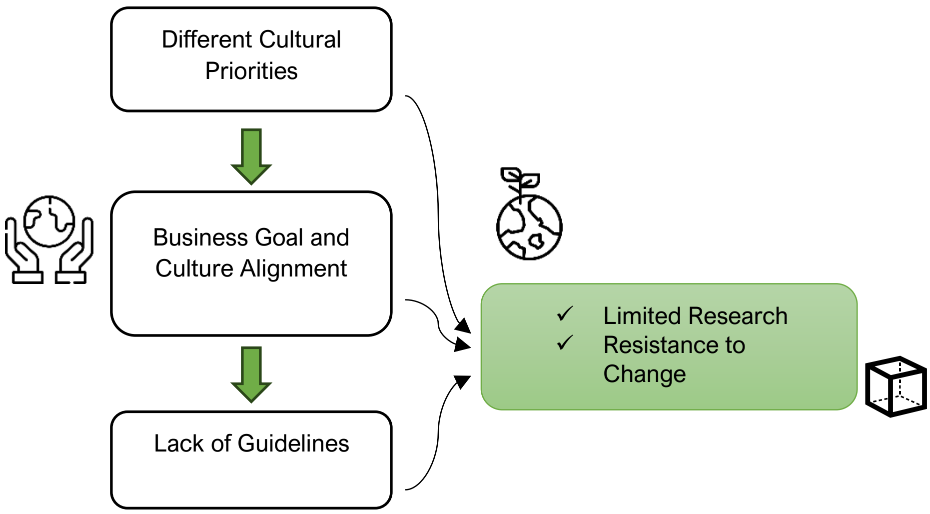

Figure 1. Business and Cultural Issues in 3D Design

The primary objectives of business and cultural impacts on sustainability in 3D design modeling are to assess how business practices and cultural values affect sustainability in 3D design (Uguz Arsu & Sipahi Döngül, 2023)This involves evaluating the influence of business practices on sustainable design, identifying cultural impacts, balancing business goals with cultural considerations, and developing guidelines and innovations for effectively integrating business and cultural factors into 3D design modeling (Nunes et al., 2022).

Cultural Impacts and Sustainability in 3D Design Modeling

Cultural impacts significantly influence sustainability in 3D design modeling, as different cultural dimensions shape design practices and priorities (Wang, 2023). According to theories like Geert Hofstede's cultural dimensions, aspects such as individualism vs. collectivism, uncertainty avoidance, power distance, and long-term vs. short-term orientation affect how various cultures approach sustainability (Kheirandish et al., 2020). In individualistic societies, there is often a focus on personal responsibility and innovation, leading to unique and environmentally friendly design solutions that align with personal values (Beugelsdijk & Welzel, 2018). Meanwhile, collectivist cultures emphasize community welfare and shared benefits, creating designs that prioritize collective goals and cultural values (Nie & Wang, 2021).

In cultures with high uncertainty avoidance, there is a preference for established sustainability practices, as these societies tend to avoid experimental solutions that may involve risk (Popenoe et al., 2021). On the other hand, cultures with low uncertainty avoidance are more open to new technologies and innovations, encouraging creative approaches to sustainable design. Power distance also influences decision-making in sustainability (Stępień & Dudek, 2021). In high power distance cultures, upper management typically makes sustainability decisions, which may limit the input of lower-level employees and affect the integration of diverse perspectives (Cope et al., 2022). Conversely, collaborative decision-making is common in low power distance cultures, resulting in more inclusive sustainability practices (Ayokanmbi & Sabri, 2021).

Additionally, long-term oriented cultures tend to focus on enduring sustainability efforts, valuing designs that emphasize durability and efficient resource use. In contrast, short-term oriented cultures may prioritize immediate results and practical solutions, sometimes overlooking long-term environmental impacts (Salam et al., 2022). Recognizing these cultural dimensions allows businesses to align their sustainability strategies with cultural values, making 3D design solutions more relevant and effective across different cultural contexts (Akbarieh et al., 2020).This alignment helps ensure sustainability initiatives are more successful and accepted within various markets (Simonazzi et al., 2020). Tailoring design solutions to cultural contexts enhances the effectiveness of sustainability practices and ensures that these designs are both environmentally responsible and culturally sensitive. This approach leads to more comprehensive sustainability efforts that resonate with diverse cultural norms, improving the overall impact of 3D design modeling on sustainability (Cope et al., 2022). The understanding and applying cultural dimensions, businesses can create frameworks and guidelines that integrate business objectives and cultural values. Such strategies help develop 3D designs that meet sustainability goals while being appropriate for the cultural environments in which they are implemented (Li et al., 2022). Ultimately, this approach fosters more responsible, inclusive, and culturally aware sustainability practices in 3D design. To assess the correlation between cultural values and the Impact of Business and Culture on Sustainability in 3D Design Modeling, the research framework can be seen in Figure

Hypotheses Development

Exploring the impact of cultural values on sustainable practices in 3D design modeling reveals significant insights. Collectivism, which emphasizes group goals over individual interests, fosters collaboration crucial for sustainable design(Chen & Unal, 2023). In collectivist cultures, loyalty and collective commitment enhance sustainability efforts. Thus, it is hypothesized that:

H1: Collectivism positively influences the adoption of sustainable 3D design practices through increased collaboration and collective responsibility.Masculinity and femininity also play a role in shaping sustainable design approaches. Masculine cultures, prioritizing efficiency and competitiveness, often focus more on productivity than on sustainability(Casciani et al., 2022). Conversely, feminine cultures, which value care and quality of life, are more inclined toward environmentally responsible design practices.

H2: Masculine cultures prioritize efficiency over sustainability in 3D design, while feminine cultures are more likely to adopt environmentally sustainable design practices.Uncertainty avoidance affects how structured and risk-averse sustainable practices become. Cultures with high uncertainty avoidance favor clear, data-driven processes, leading to more controlled and systematic approaches in 3D design.

H3: High uncertainty avoidance positively impacts the adoption of sustainable 3D design through structured, risk-minimizing approaches. Power distance influences decision-making and creativity. In low power distance cultures, where decision-making is more inclusive, greater creativity and innovation in sustainable 3D design are encouraged(Ayokanmbi & Sabri, 2021).

H4: Lower power distance enhances the implementation of sustainable 3D design through inclusive decision-making and creativity.Long-term orientation focuses on future goals, aligning well with sustainability principles. Cultures with a long-term perspective are more likely to integrate sustainable practices into 3D design, considering future impacts (Casciani et al., 2022).

H5: Long-term orientation promotes the adoption of sustainable 3D design practices by emphasizing future-focused environmental goals. Finally, indulgence versus restraint impacts sustainability through resource management (Helo & Hao, 2022). Restrained cultures, emphasizing moderation and conservation, are more inclined to adopt sustainable 3D design practices with minimizing waste.

H6: Restrained cultures are more likely to implement sustainable 3D design practices due to their focus on resource efficiency and conservation. These hypotheses highlight how cultural values significantly influence sustainable practices within 3D design modeling, can be seen in Figure 2

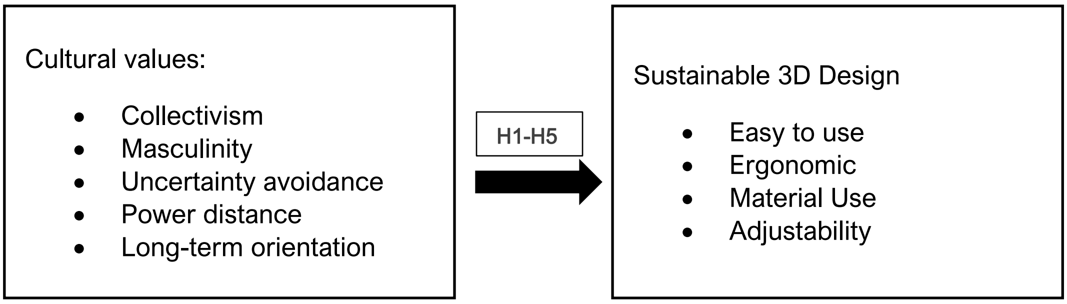

Figure 2. Hypotheses Evaluation

Methodology

The research was sustainability design, in general, measures the environmental impacts of individual designs across the product life cycle, including the effects of materials, manufacturing, assembly, transportation, use, and disposal, and provides alternatives early in the design cycle, providing actionable environmental results and recommendations (Gajdzik, 2023). Solidworks focuses on rapidly creating 3D solid models of the design and complex parts and assemblies in 3D on screen rather than flat 2D drawings, resulting in faster design development and detailing. The ability to visualize and communicate has improved (Hosen et al., 2024). Therefore, there are many characteristics in Solidworks that center on producing a product through sustainability (Palad, 2023), which can be shown in Figure understanding technology requirements and building prototypes for business and cultural impacts on sustainability in 3D design modeling, which can be shown in Figure 3.

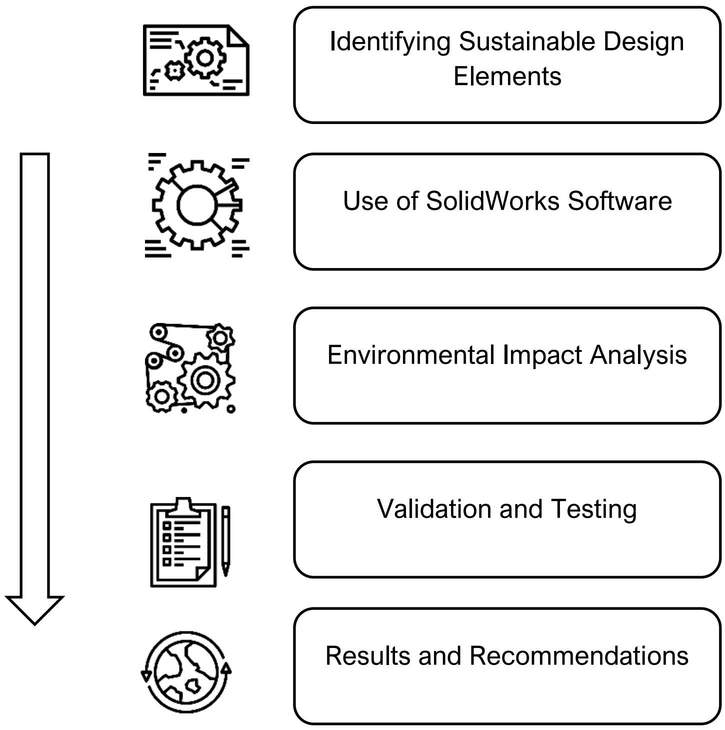

Figure 3. Flow of methodology

Data Collection

The data collection process begins once the researcher has identified the study's issues and determined the type of data needed and the most efficient collection methods. Typically, two data types are used in research: primary and secondary. Primary data refers to newly collected information by the researcher, while secondary data comes from existing sources and previous studies. Primary data is gathered through observation, interviews, and questionnaires, whereas secondary data is obtained from reports, databases, and government publications (Cannavacciuolo et al., 2023). The data in this study was used to analyze how cultural preferences affect 3D Design Modeling. First, the quality and reliability of the data were assessed to ensure accuracy. Once validated, the hypotheses were tested using the partial least square-structural equation modeling (PLS-SEM) technique with SmartPLS (version 3, SmartPLS GmbH, Bonningstedt, Germany) to validate items in the CFA and develop hypotheses. The data was further analyzed by reviewing the LOC and HOC measurement models when interpreting HCM results (Grabowska et al., 2022). HOC focuses on correlations between LOCs, serving as path coefficients in PLS-SEM. These relationships reflect structural loadings or weights, aiding researchers in understanding the complexities of human capital management (HCM), which helps optimize decision-making and organizational performance (Ayokanmbi & Sabri, 2021). The data analysis continued using SmartPLS for the model's reflective and formative measures. HCM was applied to assess how constructs like Raw Material, Manufacturing, Product Use, and End-of-Life attributes (LOC) relate to customer preferences in 3D Design Modeling (HOC). The data collection included 51 questionnaires from designers in Malaysia, with a sufficient sample size. Respondents included 22 males (43.1%) and 29 females (56.9%), and most were aged 20-29 (35.3%), 30-39 (25.5%), or above 40 (19.6%). Additional information on respondents' profiles, such as occupation and academic qualifications, is provided in Table 1.

Table 1
Demographic Profile of Respondents

Demographic		**Malaysia**	
		Freq	%
Gender	Male	29	56.9
	Female	22	43.1
Age	Below 19 years old	10	19.6
	20 – 29 years old	18	35.3
	30 – 39 years old	13	25.5
	Above 40 years old	10	19.6
Occupation	Government servant	7	13.7
	Private servant	20	39.2
	Freelance	8	15.7
	Unemployed	11	21.6
	Retired	4	7.8
	Engineer	1	2
Years of Employment	< 5 Years	19	37.5
	5 – 9 Years	21	41.2
	10 Years	11	21.6
Academic Qualification	SPM/STPM	5	9.5
	Diploma	13	25.5

Bachelor's Degree	18	35.3
Master's Degree	10	19.6
Ph.D.	5	9.8

Data Analysis

This research aims to develop a process analysis of consumers and designers choosing sustainability performance in 3d Design modeling. For this analysis, data from the customers points of view are used (Filho et al., 2022). The descriptive analyses looked at the data used, how missing data was handled, how big the sample was, and how reliable the data was. After these analyses, the hypotheses were tested. The effects of the five cultural dimensions—collectivism vs. individualism, masculinity vs. femininity, uncertainty avoidance, power distance, and long-term vs. short-term orientation—on customer preferences for the 3D Design modeling re-tested by looking at the critical threshold of significance level, which is recommended for statistics calculations. The output of the outer right for the 3D Design modeling attribute construct can be used to determine what people want in terms of the 3D Design modeling attributes (Nawar et al., 2024). But first, all the model's important thresholds should be confirmed and validated. The second part discussed how to use analysis to figure out how cultural values affect the development of 3D design modeling (Hosen et al., 2024). For this analysis, the data came from the people who made the product (Palad, 2023). Interviews are conducted with different kinds of designers to find out what they think about designing 3D design modeling and how they think about cultural value. The classification of measurement is illustrated in Figure 4.

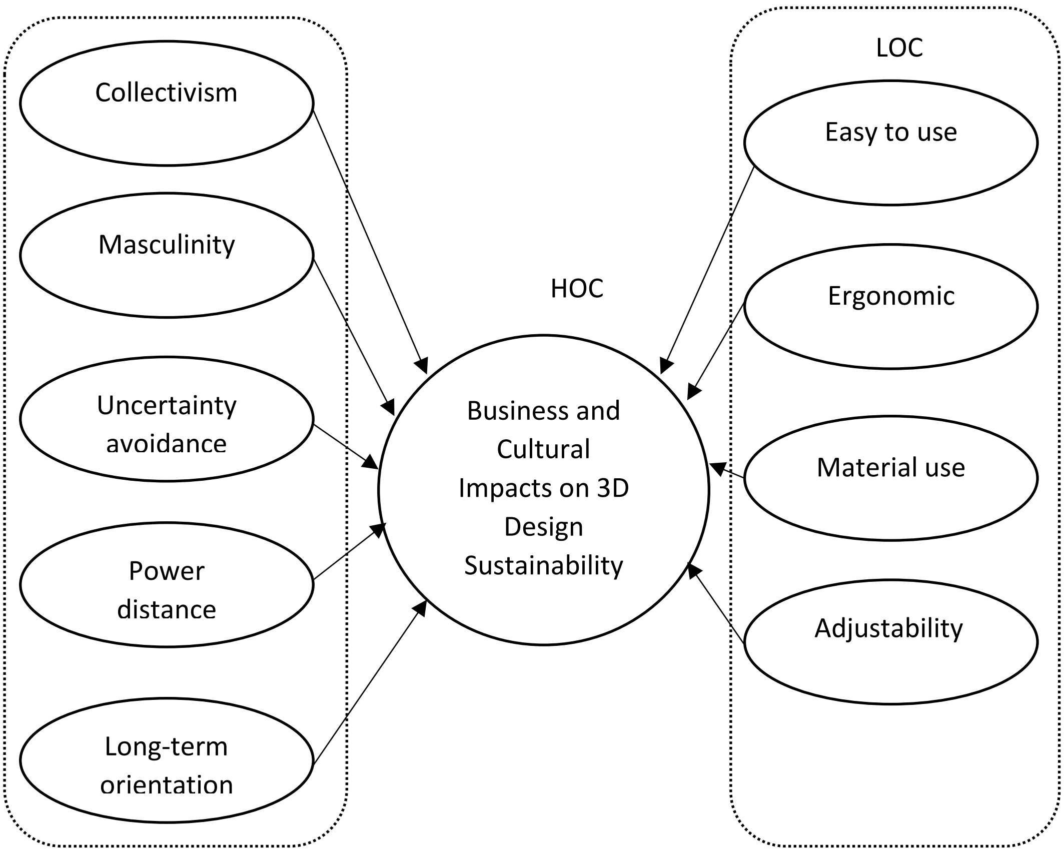

Figure 4. Classification of measurement

After establishing convergent validity, the next step was to confirm the discriminant validity. Discriminant validity is the extent to which a construct is truly distinct from the other constructs by empirical standards (Hair et al., 2016). The discriminant validity was evaluated based on the critical threshold of HTMT, which should be < 0.85 (Henseler, 2015). The results of the HTMT for Malaysia are presented in Table 2

Table 2
Discriminant Validity
HTMT value should be < 0.85 to establish discriminant validity.

	Collectivism	Power distance	Uncertainty avoidance	Long-term Orientation	Masculinity
Collectivism					
Power distance	0.107				
Uncertainty avoidance	0.089	0.569			
Long-term orientation	0.079	0.210	0.446		
Masculinity	0.109	0.332	0.331	0.681	

Based on the results shown in Table 2, the HTMT value for Malaysia was found to be 0.68. So, it was confirmed that the discriminant validity's critical threshold had been set. This means that the way cultural dimensions were put together differed from how others put them together.

Once the reflective measurements for convergent and discriminant validities have been completed, the next step was to evaluate the formative measurement model. Formative measurement in the model consists of four constructs, i.e., appearance, functionality, price, and green product characteristics. The VIF and the outer loading should be checked to evaluate the formative measurement. VIF should be < 5, and the outer loading of formative measurement should be > 0.5 (Hair et al., 2016). The results of the VIF for Indonesian and Malaysian data are presented in Table 3

Table 3
The formative measurement model

Raw Material	VIF	Manufacturing	VIF	Product Use	VIF	End of Life	VIF
Rm1	3.054	Man1	2.202	Pu1	1.787	Eol1	1.831
Rm2	1.892	Man2	1.993	Pu2	2.340	Eol2	2.337
Rm3	1.653	Man3	2.586	Pu3	1.481	Eol3	1.562
Rm4	1.960	Man4	1.759	Pu4	2.010	Eol4	2.629
Rm5	3.202	Man5	2.443	Pu5	2.256	Eol5	1.928
Rm6	1.449	Man6	1.787	Pu6	1.950	Eol6	2.080

VIF > 5 indicates a collinearity issue.

As shown in Table 3, all values of VIF for the indicators of Raw material, Manufacturing, Product use, and End of life construct are < 5. This indicates that there were no collinearity issues with the Malaysian data. After the VIF evaluations, the next step was to determine how the five cultural value dimension constructs relate to the consumer preference construct for 3D Design Modelling. In the calculation, the outer loadings of the constructs of Raw Material, Manufacturing, Product Use, and End of Life, as well as the relationships between the five cultural value dimensions for the Malaysian data. The repeated indicators of the formative-formative measurements for the Raw Material, Manufacturing, Product Use, and End of Life constructs can cause these. Hair et al. (2016) said that the formative-formative and reflective-formative measurements in the HCM could lead to a small loading and significant relationship, and the R2 could also reach the value of 1. To solve this problem, a two-stage HCM analysis can be done by getting the values of the latent variable scores from the measurements of the constructs and then turning the constructs into new indicators (Hair et al., 2016). The notation of *n* is denoted as the sample size, while *k* is the number of exogenous latentvariables used to predict the endogenous latent variables under consideration. However, in the SmartPLS version 3.0, the value of adjusted R^2 has been automatically provided. Itcan be generated by performing the bootstrapping routine. Similar to the previous evaluation on the relationships of five cultural value influences, 5000 subsamples have been run to identify the coefficient of determination.

Discussion
This study examines the impact of cultural values on sustainable practices in 3D design modeling. Collectivism is shown to significantly influence the adoption of sustainable practices(Frese, 2015). Cultures with a high degree of collectivism foster a collaborative environment that supports the integration of sustainability into design processes (Casciani et al., 2022). The effect size of 0.014 supports this finding, demonstrating that collectivism positively impacts sustainable design practices and highlighting the importance of group cohesion and shared responsibility. This result is further detailed in Table 4, which illustrates how various cultural values affect sustainable 3D design practices.

Table 4
Hypothesis Results

Hypothesis	Description	Effect Size (f^2)	Supported/Not Supported
H1	Collectivism enhances sustainable 3D design practices	0.014	Supported
H2	Masculinity prioritizes efficiency over sustainability in 3D design	0.001	Not Supported
H3	High uncertainty avoidance positively impacts sustainable 3D design	0.000	Not Supported
H4	Low power distance enhances sustainable 3D design practices	0.002	Not Supported
H5	Long-term orientation promotes sustainable 3D design practices	0.011	Supported
H6	Restrained cultures adopt sustainable 3D design practices	0.000	Not Supported

$^*p< 0.01$, $^{**}p< 0.05$, $^{***}p< 0.1$

In contrast, masculinity and femininity have differing effects on sustainability in 3D design. Masculine cultures, which focus on efficiency and competitiveness, have an effect size of 0.001, indicating minimal support for sustainable design practices (Nawar et al., 2024). This suggests that these cultures often prioritize productivity over environmental considerations. Feminine cultures, known for their emphasis on care and quality of life, tend to be more supportive of sustainable practices, though specific details for femininity were not included in the results (Hussein et al., n.d.). Uncertainty avoidance and power distance also influence the effectiveness of sustainable design practices(Stępień & Dudek, 2021). The effect size for uncertainty avoidance is 0.000, showing no significant impact on sustainability efforts. Similarly, power distance, with an effect size of 0.002, does not significantly enhance the adoption of sustainable practices (Kheirandish et al., 2020). However, long-term orientation, with an effect size of 0.011, is supported as a positive factor influencing sustainable design practices, reflecting its role in promoting future-oriented design strategies (Canetta et al., 2023). These findings, as summarized in Table 4, emphasize the need to address cultural factors to enhance the effectiveness of sustainable 3D design practices.

Conclusions

The growing emphasis on sustainability across various sectors highlights the necessity of embedding sustainable principles into 3D design modeling. Achieving this requires addressing environmental and economic concerns and recognizing the vital influence of cultural factors, as these components collectively shape the effectiveness of sustainable design strategies. Cultural values, in particular, play a pivotal role in guiding design choices, determining customer preferences, and shaping the adoption of sustainable technologies. As companies seek to balance profitability with environmental responsibility, it is essential that they also consider cultural diversity to ensure their strategies are both globally relevant and locally effective. This requires the development of comprehensive frameworks that harmonize business goals with cultural values to achieve sustainability. While progress has been made in integrating sustainability into 3D design, there remains a need for a deeper exploration of how cultural and business dynamics interact to influence sustainability outcomes. Cultural influences vary widely between regions, affecting consumer behavior, design preferences, and the acceptance of sustainable products and technologies. Understanding these cultural nuances is crucial for businesses to tailor their approaches effectively and foster more widespread adoption of sustainable practices. Moreover, further research is essential to refine and expand the existing frameworks, ensuring they accommodate the complex interplay of cultural, environmental, and business considerations. By continuing to explore these connections, companies can enhance their 3D design processes and contribute to broader industry-wide efforts to promote sustainable innovation and environmental stewardship. Ultimately, this approach will help businesses create more responsible, future-focused design models that align with both market demands and global sustainability goals.

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