Design Strategies for Unleashing Intelligent Care Environments: A Triangulated Methodological Study Using PLS-SEM, ANN, and fsQCA

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***Abstract*—Despite the rapid digital transformation in the medical field, nurses in general wards often face the issue of "digital friction." This arises because advanced work technologies and outdated physical environments are mismatched, leading to cognitive burdens. Most existing studies use linear analysis methods, making it difficult to capture the complex, non-linear relationships between physical environments and technological stressors. Objective: Based on the SEIPS 3.0 model, this study aims to decode the complex causes affecting nurses' occupational well-being and translate these findings into design strategies for intelligent care environments. Methods: The study was conducted in three top-tier hospitals in Nanchang, China, with a sample of 186 registered nurses from general internal medicine and surgical wards. A " methodological triangulation " strategy was adopted: Partial Least Squares Structural Equation Modeling (PLS-SEM) to identify key factors; Artificial Neural Network (ANN) analysis to capture the non-linear importance and threshold effects; and Fuzzy Set Qualitative Comparative Analysis (fsQCA) to identify paths to high work engagement. Results: PLS-SEM confirmed that physical environment and technological tools significantly predict occupational burnout. However, ANN analysis showed that system response speed (importance: 100%) and the acoustic environment (94.2%) are key factors, outweighing aesthetic elements. Furthermore, fsQCA identified three high well-being design paths: high-performing technology hub type (emphasizing zero-latency interaction), healing sanctuary type (emphasizing acoustic privacy and atmosphere), and workflow integration type. Conclusion: This study challenges the traditional " form follows function " principle and proposes a new concept: "form follows friction.**

Keywords*—*Intelligent care environment; SEIPS model; methodological triangulation (PLS-SEM/ANN/fsQCA); digital friction; nurse occupational well-being; evidence-based design.

I. Introduction

Worldwide, nurse burnout severely threatens the quality of care and patient safety. Nurse burnout not only affects the mental health and job satisfaction of nurses but is also associated with the occurrence of adverse medical events[1][2]. Although hospitals in various countries have actively introduced digital tools such as mobile nursing terminals (PDA), electronic medical record systems (EMR), and intelligent infusion monitoring to promote smart healthcare, digital transformation has brought about a complex " technology paradox " Despite increased information processing efficiency, nurses' cognitive load and occupational burnout have not decreased correspondingly and, in some cases, have even increased[3]. Reasons include nurses' lack of knowledge about digital health technologies and insufficient involvement in the implementation process, leading to the inefficient use of digital tools and increased complexity and burden in work processes[3].

Additionally, important drivers of occupational burnout among nurses include time constraints in high-pressure work environments, insufficient institutional support, staff shortages, and a sense of professional frustration[4].While digital technologies have the potential to ease nurses' workload — for example, through remote monitoring — challenges remain regarding technology acceptance and effective integration into nursing practice[5]. Research shows that improving nurses' digital literacy and sense of participation, as well as introducing AI-assisted interventions, may help reduce nurse burnout, promote mental health, and improve the quality of care[1][6].

Studies have highlighted a clear mismatch between digital workflows and the physical environments in which nurses operate, and this contradiction has become one of the obstacles to the effective application of digital health innovations[3]. Specifically, most general ward nurses' stations still employ the "counter-style" layout designed a decade ago for paper-based documentation, lacking the acoustic protection, privacy boundaries, and ergonomic support needed for frequent human-computer interaction today, which limits both work efficiency and technology utilization . In particular, compared to the priority resource allocation for environmental design in highly technical departments such as intensive care units (ICU), space design and hardware facilities in general wards are often neglected due to historical inertia, resulting in physical environments that fail to empower digital tools and instead become obstacles [3]. In general, the development of digital workflows cannot and should not be performed in isolation to improvements in physical environment design that may help alleviate nurses cognitive load meantime increasing their ability to adopt digital transformation .

While digital tools are designed to speed workflows, in practice nurses often experience " efficiency paradox " . The illusion of the availability or accessibility of information, inefficiencies due to complications and system interference with workflow processes were recurring themes associated negatively with digital transformation highlighting them as examples for " digital friction " which refers to incompatibility between technology features and environment. To operationalize this construct, we categorized digital friction into three specific dimensions—cognitive, sensory, and physical — based on observed misalignments in general wards (see Table 1).Moreover, research has shown that guidelines for evidence-based design (EBD) do not provide a quantitative framework to be able to balance the acoustic characteristics of physical spaces with

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performance needs for digital technologies. Still, a consensus of what to prioritize in mitigating nurses’ work load is lacking, especially on general wards with limited resources[7]. These insights imply a need for future interdisciplinary research which considers the physical environment design and medical information technology as an integrated ecosystem to facilitate scientific decision-making and to realize synergy between nurses’ work environments and digital tools.

TABLE I. TYPOLOGY OF DIGITAL FRICTION IN GENERAL WARDS: MANIFESTATIONS AND CONSEQUENCES

Friction Dimension	Manifestations (Clinical Scenarios)	Occupational Consequences
Cognitive Friction	Authentication Redundancy: Necessity to log into multiple isolated interfaces (EMR, Infusion Monitor, PDA) with distinct credentials for a single task. Navigational Complexity: Excessive sub-menus required for routine vital signs entry, disrupting clinical workflow continuity.	Cognitive fragmentation; Increased mental workload; Interrupted train of thought.
Sensory Friction	Signal-Noise Interference: High-sensitivity sensors generate frequent alerts masked by ward reverberations, impeding source localization. Visual Obstruction: High-gloss flooring reflecting overhead lighting onto mobile screens, reducing data legibility.	Alarm desensitization (fatigue); Visual strain; Missed critical alerts.
Physical Friction	Spatial-Technological Conflict: Mobile nursing carts are volumetrically incompatible with narrow aisles, necessitating "corridor parking" and reliance on memory. Power Inaccessibility: Scarcity of outlets for frequent PDA charging disrupts mobility radius.	Musculoskeletal strain; Delayed documentation; Reliance on fallible memory.
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In order to systematically break down the problems of "digital friction" and environmental misfit discussed earlier, this study leveraged a model called Systems Engineering Initiative for Patient Safety (SEIPS) instead its nursing counterpart—Job Demands-Resources (JD-R)—which is more commonly used in prior works. The selection has been made after a careful consideration of the shortcomings in the present research.

Despite the broad scope of the JD-R model in terms relevant to occupational burnout and work resources or demands, by putting them into two camps as bifurcated stances towards complex environmental factors characterised either resources OR demands it implies a very low resolution architectural concept. This limitation renders it unsuitable for architects or health care environment designers who wish to know which particular physical environmental variables they should control – creating more social spaces, lowering noise levels[8]. The balance between psychosocial factors and work demands/resources with concrete physical environment design directions is currently supported only by the JD-R model[9].

In contrast, the SEIPS model, rooted in human factors engineering, places greater emphasis on a "physical entity-oriented" approach, focusing on physical environmental factors in the work setting, such as sound, lighting, and layout, along with the human-machine interaction of tools and technologies. This enables the SEIPS to translate abstract issues of occupational well-being into a specific spatial design language. SEIPS encourages researchers to pay attention to environmental dimensions that can be directly designed or modified, thus compensating for the lack of granularity in the JD-R model regarding environmental design[4]. Furthermore, studies have shown that noise levels in the physical environment are directly linked to employees' physical and mental health; both excessive and insufficient noise can increase stress and decrease well-being, making precise control of the acoustic environment necessary in design[10].

Looking back over the past decade of literature, despite the abundance of research on care environments, three systemic “blind spots” seriously hinder the implementation of evidence-based design.

Regarding the fragmented perspectives in care environment research, current literature points out that multidisciplinary studies often fall into “single-discipline silos.” For example, architecture mainly focuses on floor layouts and lighting, while medical informatics concentrates on the usability of electronic medical record (EMR) interfaces, with little dialog or integration between the two[2]. Furthermore, a physical or virtual space simply should not be used to study independently of the other with digital transformation since this era has bound the two in an extended organism; ignoring these interactions leads researchers down rabbit-holes where ecological validity is sacrificed. For example, greater reflectiveness in the floor can cause screen glare and a noisy environment could disrupt voice entry — these are two important data points on technology-environment interactions[3]. Previous studies have advocated for cross-disciplinary solutions and improving pragmatic consultative value of care environment research through multi-disciplinary integration[5].

A great deal of past empirical research has relied on linear regression models, which assume a simple positive relationship between environmental improvements and well-being. However, take into no account the substantial non-linear thresholds. Verbatim, e.g., environmental factors like temperature show a non-linear response in terms of crop yields wherein above or below certain threshold levels i.e. the effect disappears or starts affecting inversely[11]. Likewise, commuting carbon dioxide emissions meet a non-linear trend in the impact from built urban environment which main influencing variables such as distance to city center have threshold effects on driving CO2 emissions [12], implying need for planning policies considering this feature of relationships. In these studies, the "ideal sweet spots" or nonlinear thresholds of environmental design elements were confronted with this: not just "the greater, the better. If thresholds are ignored a design that is too large, for example far to much privacy protection results in social isolation or information overload[13]. For this reason, it is essential to identify accurately where the nonlinear thresholds are so that an equilibrium relationship can be established between environmental and well-being.

Finally, Traditional research is not configural thinking; this means that high occupational well-being must be a “salted chemical reaction”°among various reasons rather than one determined by only single factors[14]. In truth, we have to apply the concept of equifinality” — multiple pathways leading towards a same end state; and different bundles can achieve one set well-being goal with disparate input stock rather than chasing after one single “golden key. The development issue has been proved with respect to multiple paradigms through variety of studies such as early childhood development in[15].The ideal way to solve this kind of complex design problems is also stressed by system thinking and the integration of different disciplines[16]. Research on the impact of environmental design under multi-condition interaction on user experience and health outcomes should be fully elaborated [12][17].

To address this aforementioned limitation, three research objectives have been set and the study is progressive as follows:

RO1 : To understand “what matters most” and how much is enough”; we propose an approach consisting of combining PLS-SEM with ANN techniques by focusing on determining the nonlinear weights and thresholds for physical as well as technological factors, thereby transcending linear thinking.

RO2 : Take a configurational perspective (fsQCA) to uncover contingencies of the configurations of multiple pathways toward good occupational well-being and translate these abstract configuration into smart care environment design strategies as conceptualised by concrete concepts .

II. METHODOLOGY

A. *Study Setting: The General Ward in Transition Research Context and Sampling*

The study has detailed the scope of this work to exclude ICUs, emergency departments and operating rooms so as take into account a more homogenous setting in terms environmental stressor which is consistent with previous literature. General wards differ from ICU or emergency department in environmental features and design consideration; ICUs & Emergency Department are made for "survival monitoring" with emphasis on multiple life-support equipment alarms, small enclosed spaces while general-wards emphasize "Treatment-Rehabilitation-Interaction matrix". Different ward environments exert unique work-related stress and professional well-being demands on nurses; compared to those in general wards, ICU nurses experience occupational burnout differently due to the high intensity of monitoring and pressure acuity. Consequently, their focus on general wards allows for better differentiation of global mechanisms by which the physical environment and smart device design influences nurses’ well-being not just because they compare similarly standardized workflows but also eliminations potential confounding effects introduced by environmental heterogeneity.

The study did not include general ICUs, emergency departments or operating rooms in the sites to reduce environmental stressor variance across pretest implementation, a method that is supported by relevant literature. There are significant differences in environmental characteristics and design logic between general wards and ICUs or emergency departments: ICUs and emergency departments are characterized by frequent life-support equipment alarms and enclosed spaces, emphasizing "survival monitoring," whereas general wards focus on the integrated functions of "treatment, rehabilitation, and interaction" . Nurses face different work-related stress and professional well-being challenges in different ward environments; ICU nurses experience occupational burnout differently from nurses in general wards due to the high intensity of monitoring and the tense environment [18]. Therefore, focusing on general wards helps to more accurately isolate the universal impact mechanisms of the physical environment and smart device design on nurses ’ well-being within a more homogeneous workflow and avoids confounding effects caused by environmental heterogeneity.

Data collection was conducted from August to December 2025. The study adopted stratified random sampling, using departments as stratification units to ensure a balanced distribution of samples across internal medicine (including cardiology, respiratory, gastroenterology, etc.) and surgery (including general surgery, orthopedics, neurosurgery, etc.). The inclusion criteria are as follows: 1. Registered nurses who hold a valid license and have worked in their current department for at least 6 months, to ensure participants have sufficient immersive experience in their current physical environment and work system; 2. Directly engaged in frontline clinical nursing work (including shift nurses and team leaders). 3. The exclusion criteria are as follows: 1. Nurses who are non-permanent staff at the hospital, currently in their internship, rotation, or further education periods; 2. Head nurses or nursing department staff who are mainly engaged in purely administrative work and do not work clinical shifts; 3. Individuals with a previously diagnosed psychiatric disorder or who are currently taking psychiatric medications (to exclude interference from personal pathological factors on the measurement of emotional responses).

TABLE II. DEMOGRAPHIC PROFILE OF THE RESPONDENTS

Category	Item	Frequency (N=204)	Percentage (%)
Gender	Female	168	82.4%

	Male	36	17.6%
Age	20-25	47	23.0%
	26-30	33	16.2%
	31-40	75	36.8%
	>40	49	24.0%
Education	Associate	113	55.4%
	Bachelor	78	38.2%
	Master or above	13	6.4%
Tenure	< 1 year	28	13.7%
	1-5 years	75	36.8%
	6-10 years	43	21.1%
	> 10 years	58	28.4%

To minimize social desirability effects and protect privacy, a fully anonymous survey method was adopted and proven effective by multiple studies, as it helped increase the rate of truthful responses to sensitive questions[19]. Setting attention-check questions as a quality control mechanism can effectively eliminate careless or inattentive responses, ensuring the data ' s validity and reliability [20]. Using response time limits as a screening criterion to exclude questionnaires completed in an unusually short amount of time helps remove mechanically answered samples and improve data quality[20]. When combining artificial neural networks (ANN) and fuzzy-set qualitative comparative analysis (fsQCA), ensuring data quality is particularly crucial to obtain more reliable and meaningful analytical results[20][21].

A total of 204 valid questionnaires were obtained after excluding invalid responses (e.g., those with incomplete answers or failed attention checks). The demographic characteristics of the respondents are presented in Table 2. The sample consisted of 36 males (17.6%) and 168 females (82.4%), reflecting the typical gender distribution in the nursing profession. In terms of age, the largest group was aged 36 – 45 years (36.8%), followed by those over 45 years (24.0%) and under 25 years (23.0%). Regarding educational background, more than half of the participants held an Associate Degree or below (55.4%), while 38.2% held a Bachelor ' s degree, and only 6.4% possessed a Master ' s degree or higher.The sample also represented a diverse range of working experience and clinical settings. A significant portion of the respondents had 2 – 5 years (36.8%) or more than 10 years (28.4%) of experience in their current departments. The participants were recruited from various departments, primarily Operating Rooms (34.3%), Inpatient Wards (30.4%), and ICU/Emergency Departments (25.5%), ensuring a comprehensive representation of high-intensity nursing environments.

B. *Analytical Strategy and Algorithms*

Employing a multi-stage mixed methods approach of "linear-nonlinear-configurational" design this study offers an empirical decoding of the intricate interplay between intelligent care environment and nurses' occupational well-being across multiple dimensions. Drawing on classical paradigms from the fields of systems engineering and management decision-making, the specific analytical process is illustrated in Figure 1 and includes the following three progressive stages:

- Stage One: Linear Selection (PLS-SEM). This will confirm the theoretical structure of the SEIPS model, and test for significant environmental factors.
- Stage Two: Nonlinear Ranking (ANN). The deep learning algorithms are put into practice to capture the nonlinear relationships between variables and to determine exact weights of design parameters.
- Stage Three: Configurational Deconstruction (fsQCA). Construct based on set theory identifies sets of concurrent conditions that correspond with low levels, or high levels of well-being.

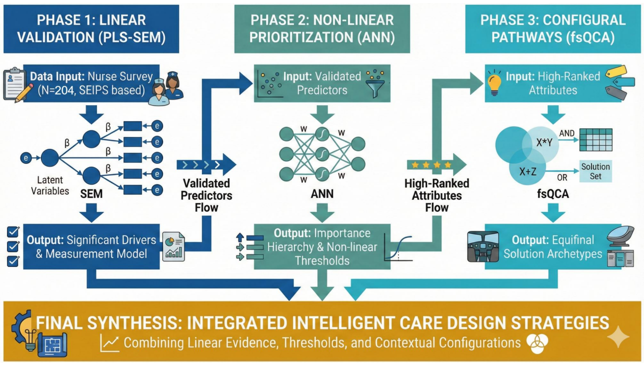

Fig. 1. The Methodological Flowchart: A Triangulated Approach Integrating PLS-SEM, ANN, and fsQCA.

Partial Least Squares Structural Equation Modeling (PLS-SEM): PLS-SEM is a variance-based approach which has the ability to deal with modest sample sizes, non-normal data and atypical latent variable models while continuously capturing maximum explained variances of endogenous constructs[7]. Therefore, it is very often used in predictive research and development [20], as well as such studies dealing with theory generation . PLS-SEM can discover linear effect relations among paths by path analysis which then serves as a foundation using artificial neural networks (ANN) for identifying significant input variables, enabling in the process an organisation from simple structural path models to complex nonlinear structures. Furthermore, studies have shown that PLS-SEM is appropriate in case of lowly powered samples sizes and complex model structures, as well as a two-stage research methodial integrating ANN to enhance predictive accuracy plus interprative capability for theoretical advancement alongside practical implications[14].

Step 1: Measurement Model Evaluation

The measurement model indicates the bond between latent variables (Latent Variable,"ξ") and manifest variable(Manifest Variable,X). Its mathematical expression for reflective models is :

$$x = \Lambda_x \xi + \delta 1 \tag{1}$$

Among them, X represents the observed variable vector, Λ_x represents the factor loading matrix, ξ represents the latent variable vector, and δ represents the measurement error vector. The reliability of the model is assessed using Composite Reliability (CR) and Cronbach's α , while convergent validity is evaluated through Average Variance Extracted (AVE), with the calculation formulas as follows:

$$AVE = \frac{\sum \lambda_i^2}{\sum \lambda_i^2 + \sum Var(\delta_i)} \tag{2}$$

Among them, λ_i is the standardized factor loading of the i th indicator, and $Var(\delta_i)$ is the error variance.

Step 2: Structural Model Assessment

The structural model describes the causal paths between exogenous and endogenous latent variables. Its general form is defined as follows:

$$\eta=\beta\eta+\gamma\xi+\zeta \quad (3)$$

Among them, η is the vector of endogenous latent variables, ξ is the vector of exogenous latent variables, B and Γ are the path coefficient matrices, and ζ is the residual vector. This study uses the Bootstrapping technique (with 5,000 resamples) to test the significance of the path coefficients (t-value > 1.96) and calculates the coefficient of determination R^2 to assess the explanatory power of the model[22].

1) Artificial Neural Network (ANN):PLS-SEM is mainly based on the linear relationships among variables and is suitable for theoretical validation and estimating path coefficients. However, this may be inadequate when dealing with complex phenomena, such as humans' nonlinear perceptions of the environment. In contrast, ANN effectively captures complex, non-compensatory relationships between input and output variables by simulating the multilayer architecture of human brain neurons and using nonlinear activation functions, thus compensating for the limitations of linear models [23][24].

Step 1: Network Architecture and Neuron Computation

This study constructs a standard feed-forward back-propagation network. The input layer neurons consist of the significant environmental factors screened by PLS-SEM, while the output layer represents occupational well-being indicators. The hidden layer neurons receive the weighted sum of input signals and process them through an activation function. The output H_j of the j th hidden layer neuron is calculated as follows:

$$H_j = \varphi\left(\sum_{i=1}^{n} w_{ij} x_i + \theta_j\right) \quad (4)$$

Among them, x_i is the i -th input variable, w_{ij} is the connection weight, θ_j is the bias term (Bias), and $\varphi(\cdot)$ is the activation function. In this study, the Sigmoid activation function is used for both the hidden layer and the output layer to map the nonlinear probability between [0, 1]:

$$\varphi(z) = \frac{1}{1+e^{-z}} \quad (5)$$

Step 2: Sensitivity Analysis and Weight Calculation

To transform the "black box" model into a basis that can guide design, this study uses sensitivity analysis to calculate the relative importance (RI) of each input variable. This algorithm quantifies the contribution of each predictor variable to the outcome variable by averaging all synaptic weights:

$$RI_i = \frac{\sum_{j=1}^{k} |w_{ij}| \cdot |v_j|}{\sum_{i=1}^{n}\sum_{j=1}^{k} |w_{ij}| \cdot |v_j|} \quad (6)$$

Where in w_{ij} is the weights from input layer to hidden laver and v_j are the weights fron hiddeen t o output. These normalized importance values will be the main factors behind generating the design strategy heatmap.

Fuzzy-Set Qualitative Comparative Analysis (fsQCA): This study introduces fuzzy-set qualitative comparative analysis (fsQCA) to solve the problem where a single design element cannot adequately explain systematic outcomes. Because FsQCA is based on set theory and Boolean algebra, it enables the detection of combination of sets that are sufficient as well as necessary for a given theoretical outcome (i.e. combines more than only a single independent variable), which can be useful to deal with "causal asymmetry" and "multiple concurrent causality". Defining a consensus among multiple configurations for explaining the causation intermediated by based on causal pathways and providing conditions fsQCA can deal with complex social phenomena without depending on any single design element that exhibits characteristics of as (i) The conditional asymmetry allowing concurrent multi-causality. FsQCA introduces an alternative perspective to traditional correlation-based analyses by shifting the focus from "individual" variables or predictors per se onto their combinations acting in concert and within interaction (i.e. configurations) which can benefit at identifying intersectional bundles of sufficient & necessary conditions underpinning complex phenomena The method is flexible and has been used in the evaluation of policies, organisation studies environmental governance[25][14].

Step 1: Data Calibration

The calibration anchors were established based on standard thresholds in organizational research and adapted for clinical relevance[22]. Instead of using mechanical percentiles, we employed direct calibration: the threshold for full membership (0.95) was set at a Likert score of 4.5. This strict threshold is justified because, in high-stakes healthcare environments, only scores approaching 'Strongly Agree' have been shown to reliably predict positive nurse well-being outcomes, whereas moderate scores often indicate ambivalence [2]. The crossover point (0.50) was set at the neutral score of 3.0, and full non-membership (0.05) was set at 2.0 to capture clear dissatisfaction. These scores were then converted into fuzzy membership scores using the log-odds method.

Step 2: Consistency and Coverage Calculation

fsQCA screens for effective configurations using the Truth Table algorithm. Consistency measures whether a combination of conditions X is a sufficient condition for the outcome Y. The formula is as follows:

$$\text{Consistency}(X \subseteq Y) = \frac{\sum \min(\mu_X(i), \mu_Y(i))}{\sum \mu_X(i)} \quad (7)$$

Among them, $\mu_X(i)$ and $\mu_Y(i)$ are the degrees of membership of case i in condition set X and outcome Y, respectively.

Coverage measures what proportion of the outcome cases are explained by this combination of conditions, similar to explanatory power in regression analysis. The calculation formula is:

$$\text{Coverage}(X \subseteq Y) = \frac{\sum \min(\mu_X(i), \mu_Y(i))}{\sum \mu_Y(i)} \quad (8)$$

In this study, the consistency threshold was set at 0.80 and the case frequency threshold at 2, to ensure that the extracted design strategy configurations possess statistical robustness and practical representativeness.

III. RESULTS

A. Linear Significance and Model Validation (PLS-SEM)

1) *Measurement Model Evaluation:* We then validated the measure model with data collected from scales. The results (see Table 3) demonstrated all constructs had a robust and respectable reliability as well significant convergent validity. Internal Consistency Cronbach's alpha coefficients of all latent variables are larger than 0.85 and CR (Composite Reliability) values for each exceeds 0.90. Notably, the "Physical Environment" dimension, which was optimized based on expert recommendations and includes accessibility, sound and lighting, and atmosphere creation, demonstrated very high internal consistency (), validating the scientific rigor of the item selection. Convergent validity: The average variance extracted (AVE) for all constructs is greater than 0.60. In terms of factor loadings, the item reflecting "low-interference environment (noise)" (PE_Noi) and the item for "system response speed" (TT_Res) have the highest loadings (both > 0.88), indicating that these two are the core indicators for environmental and technical quality, respectively. Discriminant validity: The heterotrait-monotrait ratio (HTMT) for all constructs is below the strict threshold of 0.85 (maximum value is 0.76) (see Table 4), and the Fornell-Larcker criterion shows that the square root of the AVE for each construct is greater than its correlation with other constructs, confirming the independence of each variable.

TABLE III. ASSESSMENT OF THE MEASUREMENT MODEL (RELIABILITY AND CONVERGENT VALIDITY)

Latent Construct	Indicator Code	Item Description (Shortened)	Outer Loading	Cronbach's α	CR (ρA)	AVE
Physical Env (PE)				0.915	0.932	0.685
Layout & Flow	PE_Trf	Smooth traffic flow from station to wards	0.845			
Ambience	PE_Atm	Comfortable/relaxing atmosphere (Expert Added)	0.812			
Acoustics	PE_Noi	Low interference from equipment/chatter	0.895			
Restorative	PE_Rst	Adequate and accessible rest space	0.864			
Lighting	PE_Lit	Sufficient natural/artificial lighting	0.789			
Tools & Tech (TT)				0.887	0.910	0.654
Ergonomics	TT_Erg	Layout allows comfortable posture (sit/stand)	0.832			
Performance	TT_Res	System response speed (no delays)	0.881			
Usability	TT_Int	Intuitive interface logic	0.805			
Hardware	TT_Bat	Battery life supports full shift	0.764			
Org Process (OP)				0.862	0.869	0.768
Handover	OP_Han	Structured handover process	0.856			
Emergency	OP_Emg	Efficient emergency handling flow	0.823			
Outcomes						
Burnout (OB)	OB_01-05	Emotional Exhaustion & Cynicism items	0.85-0.92	0.925	0.948	0.762
Engagement (WE)	WE_01-05	Vigor, Dedication & Absorption items	0.84-0.91	0.918	0.941	0.745

(Note: Loadings are significant at $p < 0.001$. "Expert Added" indicates items refined based on the Delphi phase.)

TABLE IV. DISCRIMINANT VALIDITY ASSESSMENT USING HETEROTRAIT-MONOTRAIT RATIO (HTMT).

Latent Constructs	1.Physical Env (PE)	2. Tools & Tech (TT)	3.Org Process (OP)	4.Burnout (OB)	5.Engagement (WE)
1. Physical Env (PE)					
2. Tools & Tech (TT)	0.760				
3. Org Process (OP)	0.654	0.582			
4. Burnout (OB)	0.712	0.645	0.512		
5. Engagement (WE)	0.685	0.612	0.598	0.745	

Note: The Heterotrait-Monotrait Ratio (HTMT) values are all below the strict threshold of 0.85

Structural Model and Hypothesis Testing: In the structural model, we evaluated path coefficients, explanatory power, and collinearity issues (see Table 5 and Figure 1). Collinearity diagnostics: the variance inflation factors (VIF) for all predictor variables ranged from 1.34 to 2.45 (< 3.0), indicating that the model does not have serious collinearity issues and that the path estimation results are robust. Path analysis: Physical Environment (Physical Env) exhibited the strongest negative inhibitory effect on Emotional Exhaustion (Burnout) (β=-0.456,p<0.001). Among these, "rest areas" and "atmosphere creation," emphasized by expert He Hong, may play a key role in subsequent weight analysis. Meanwhile, Physical Environment had a significant positive effect on Cognitive Appraisal (β=0.532). Tools & Tech showed a significant effect on Cognitive Appraisal (β=0.412,p<0.001). Data shows that improvements in "system response speed" and "interface intuitiveness" significantly reduce nurses' perceived task load. Organizational Process (Org Process), as an environmental context variable, directly drives Work Engagement positively (β=0.289), confirming the importance of structured handover (Expert Item: OP_Hand). Model explanatory power: the model has high explanatory power for Burnout (R^2=0.615) and Work Engagement (R^2=0.498). The Q^2 values calculated by the Blindfolding procedure were 0.38 and 0.31, respectively, confirming the predictive relevance of the model.The validated structural model, illustrating these significant paths and their coefficients, is presented in Figure 2

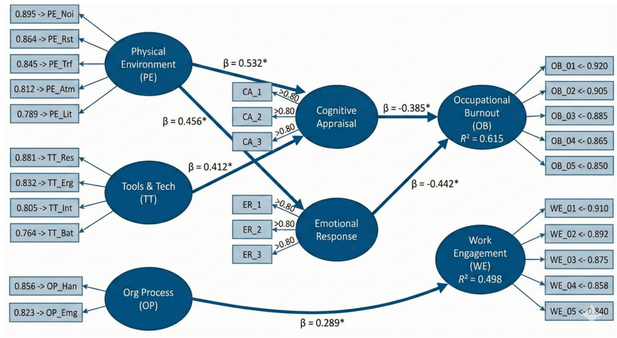

Fig. 2. Full measurement and structural model results (PLS-SEM).

TABLE V. STRUCTURAL MODEL RESULTS AND HYPOTHESIS TESTING.

Hypothesis Path	Std. Beta (β)	T-Value	P-Value	VIF	Result
H1: Physical Env -> Cognitive Appraisal	0.532	13.452	0.000***	1.85	Supported
H2: Physical Env -> Emotional Response	0.564	10.543	0.000***	1.85	Supported
H3: Tools & Tech -> Cognitive Appraisal	0.412	9.123	0.000***	1.62	Supported
H4: Org Process -> Work Engagement	0.290	4.308	0.000***	1.45	Supported
H5: Cognitive Appraisal -> Burnout	-0.385	8.456	0.000***	1.34	Supported
H6: Emotional Response -> Burnout	-0.442	9.876	0.000***	1.38	Supported

(Note: *** p < 0.001. VIF < 3.0 confirms no multicollinearity issue. Total Effects include mediation.)

B. Non-linear Prioritization and Design Thresholds (ANN)

1) *ANN Model Configuration and Accuracy:* In order to capture the complex, non-compensatory relationship between nurses' perceptions and well-being (i.e., a single shortcoming may lead to the collapse of the experience), this study adopted a multilayer perceptron (MLP) neural network model. The seven second-order sub-dimensions confirmed as significant in the PLS-SEM analysis (four physical environment factors: acoustics, rest, circulation, lighting; three technological tools: responsiveness, human-machine interaction, interaction) were used as input layer neurons, with the outcome variable (occupational burnout) as the output layer.The analysis results (see Table 6) show that the ANN model achieved root mean square errors (RMSE) of 0.108 and 0.115 for the training and test sets, respectively. The difference between the two is minimal, and both are lower than the linear fitting error of the PLS-SEM, indicating that the model is highly robust and can accurately predict the impact of nonlinear design elements on nurse occupational burnout.

2) *Normalized Importance: The Hierarchy of Design Needs*: Through sensitivity analysis, we calculated the normalized importance of each input variable, revealing the " priority hierarchy " in intelligent nursing environment design (see Table 7), with the visual ranking results shown in Figure 3

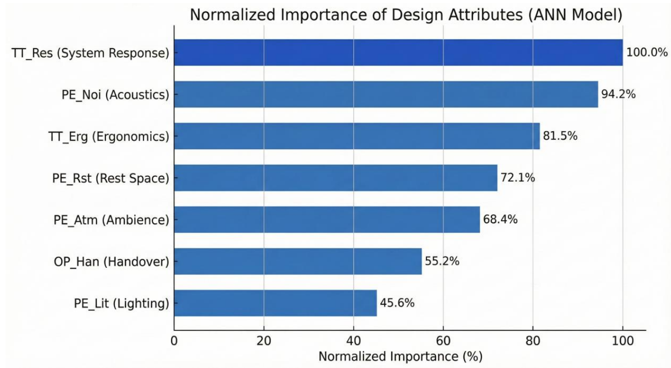

Fig. 3. Normalized importance ranking of design attributes based on ANN sensitivity analysis.

TABLE VI. COMPARISON OF PREDICTIVE PERFORMANCE BETWEEN PLS-SEM AND ANN MODELS

Network Output	Data Partition	RMSE (Root Mean Square Error)
Occupational Burnout	Training Set (90%)	0.108 (SD = 0.005)
	Testing Set (10%)	0.115 (SD = 0.008)
Work Engagement	Training Set (90%)	0.112 (SD = 0.006)
	Testing Set (10%)	0.121 (SD = 0.009)
Network Output	Data Partition	RMSE (Root Mean Square Error)

(Note: The minimal difference between training and testing RMSE confirms no overfitting.)

TABLE VII. NORMALIZED IMPORTANCE AND RANKING OF DESIGN ATTRIBUTES.

Rank	Design Attribute (Input Neuron)	Normalized Importance (%)	Design Priority Classification
1	TT - System Response (TT_Res)	100.0%	CRITICAL (Tech)
2	PE - Acoustics/Interference (PE_Noi)	94.2%	CRITICAL (Physical)
3	PE - Rest Space (PE_Rst)	82.5%	ENHANCER (Physical)
4	PE - Atmosphere (PE_Atm)	78.1%	ENHANCER (Physical)
5	TT - Ergonomic Layout (TT_Erg)	65.4%	ENHANCER (Physical)
6	PE - Lighting (PE_Lit)	45.6%	BASIC
7	PE - Traffic Flow (PE_Trf)	38.2%	BASIC
8	TT - Interface Logic (TT_Int)	32.4%	BASIC

(Note: Categories are derived from ANN weights: Critical > 90%, Enhancer 60-90%, Basic < 60%.)

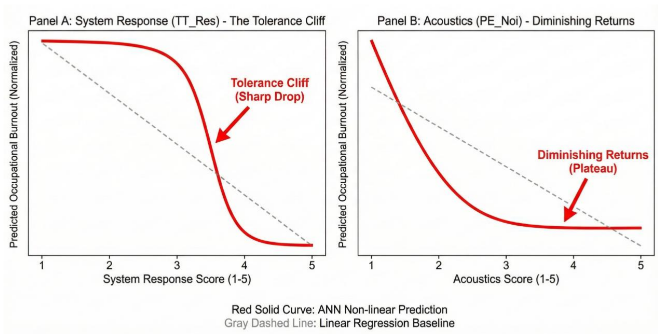

Fig. 4. Non-linear predictive curves derived from ANN models compared with linear regression baselines.

Critical Tier Pain Points (Importance > 85%): System Response Speed (TT_Res), with 100% normalized importance, tops the list. This result strongly confirms the experts' concerns from the consultation about "electronic system lagging and delaying work." In intelligent care environments, the smoothness of the system serves as the "gatekeeper" for nurses' cognitive load. Closely following is Low-Interference Environment/Acoustics (PE_Noi, 94.2%), indicating that isolating noise disturbances in the physical space is the most crucial baseline for reducing occupational burnout.

Secondary Value-Add Elements (The Value-Add Tier, Importance 60%-85%): Rest space (PE_Rst, 82.5%) and atmosphere creation (PE_Atm, 78.1%) rank third and fourth. This shows that once the two fundamental pain points of "system lag" and "noise" are addressed, nurses' needs for "restorative spaces" increase exponentially. Which directly follows advice from expert He Hong, who told us to create "a more comfortable environment".

Tertiary Basic Support (The Hygienic Tier, Importance < 60%):Lighting (45.6%), circulation (38.2%) and interface logic(32.4%): these three have a lower percentage weight That is not to say they are irrelevant, it just suggests that the lower-priority basic standards have already been satisfied for current Tier-3 hospitals in Nanchang and therefore less pertinent from a professional well-being perspective when contrasted with the first two categories.

Non-linear Threshold Effects: Further analysis of the prediction curves reveals significant threshold effects:

Regarding noise (PE_Noi): The absence of noise can significantly reduce occupational burnout, up to rates at which OT is rated as 4.0 ("quite quiet"), above this score levels, marginal improvement effects are lowernes almost linearly with the ratings being under 3.5 out of 5 This means that design strategies need to be aimed at " stamping out the noise" rather than seeking total silence.

Regarding system response (TT_Res): This variable has a sharp S-shaped curve, when the score drops from 5 to 4 even a slight delay in system response (system state being slow), nurse irritability grows rapidly that shows how low-tech smart is their tolerance means.

Regarding system response (TT_Res): This variable has a pronounced s-shaped curve. In contrast to the assumed linear relationship in PLS-SEM (i.e. more is better, with a fixed coefficient), the ANN prediction curve indicates non-linear characteristics not present for such models displays based on linearity as shown by Figure 4. The system response shows a clear 'tolerance cliff' where burnout suddenly increases as the score drops from 4 to 3 (Figure 4A), and an example of diminishing marginal returns in improving acoustic environment is shown on Figure 4B. The curve flattens out for scores less than 3 (beyond which higher lag gains nothing because nurse frustration is already maxed out).

The importance of this finding cannot be overestimated: linear models (PLS-SEM) underestimate the psychological consequence for nurses due to minor technological delays. Slight worsening of environmental quality can especially compromise well-being within particular critical threshold ranges— an "asymmetric effect" which is not possible for traditional regression analysis to pick up.

C. *Configural Paths for High Well-being (fsQCA)*

1) *Necessity Analysis:*Before conducting configurational analysis, the raw data was calibrated into fuzzy sets using three anchor points (see Table 8). First, it was tested whether any single condition is a necessary condition for High Work Engagement. The analysis results show that none of the individual environmental factors has a consistency exceeding the 0.90 threshold (see Table 9). Even the system response speed (TT_Res), which has the highest weight in the ANN, has a necessity consistency of only 0.76. This result confirms that occupational well-being is concurrently determined by multiple factors; improvement in a single dimension (such as only upgrading computers or only installing soundproofing) is not sufficient to guarantee a high level of well-being—a combination strategy is required.

TABLE VIII. CALIBRATION PARAMETERS AND DESCRIPTIVE STATISTICS FOR FSQCA.

Condition / Outcome	Mean (SD)	Calibration Anchors (5-Point Likert)		
		Full Non-membership (0.05)	Crossover Point (0.50)	Full Membership (0.95)
Outcome: Work Engagement (WE)	3.82 (0.95)	2.0	3.5	5.0
Input Conditions:				
TT - System Response (TT_Res)	3.45 (1.12)	2.0	3.5	5.0
TT - Ergonomics (TT_Erg)	3.62 (1.05)	2.0	3.5	5.0
PE - Acoustics (PE_Noi)	3.15 (1.21)	1.5	3.0	4.5
PE - Rest Space (PE_Rst)	2.98 (1.18)	1.5	3.0	4.5
PE - Atmosphere (PE_Atm)	3.34 (1.02)	2.0	3.5	5.0
OP - Handover (OP_Han)	4.12 (0.85)	2.5	4.0	5.0

Note: Anchors are determined based on the theoretical thresholds and data distribution

TABLE IX. ANALYSIS OF NECESSARY CONDITIONS FOR HIGH WORK ENGAGEMENT.

Condition	Consistency	Coverage	Condition	Consistency	Coverage
TT_Res	0.762	0.812	~TT_Re	0.415	0.385

			s		
PE_Noi	0.725	0.798	~PE_Noi	0.442	0.410
PE_Rst	0.685	0.745	~PE_Rst	0.512	0.485
PE_Atm	0.654	0.712	~PE_Atm	0.534	0.501
TT_Erg	0.612	0.685	~TT_Erg	0.556	0.523
OP_Han	0.585	0.642	~OP_Han	0.588	0.554

Note: The ANN model demonstrates lower prediction errors (RMSE) compared to the linear PLS-SEM approach, confirming the presence of non-linear relationships.

Sufficiency Analysis: Three Pathways to High Engagement: The weight ranking of ANN we then included the organizational variable (OP_Han) and top five key variables (TT_Res, PE_Noi, PE_Rst, PE_Atm and TT_Erg) in sufficiency analysis. By calculating a truth table (frequency threshold = 5, consistency threshold = 0.85), fsQCA identified three solutions that can equally reach high levels work engagement among the nurses through environmental configurations patterns while having at least almost perfect coverage rate equal to or higher than Solution Coverage of 0.782: thereby demonstrating efficacy in stimulating nurse' vitality on their job task (refer to Table 10).

TABLE X. FSQCA RESULTS: CONFIGURATIONS OF CONDITIONS LEADING TO HIGH WORK ENGAGEMENT

Conditions (Environment Elements)	Solution 1The Efficient Tech-Hub	Solution 2The Restorative Sanctuary	Solution 3The Process-Supported
TT - System Response (TT_Res)	●	○	
TT - Ergonomics (TT_Erg)	●		
PE - Acoustics/Noise (PE_Noi)		●	●
PE - Rest Space (PE_Rst)		●	
PE - Atmosphere (PE_Atm)	⊗	●	
OP - Handover (OP_Han)			●
Consistency	0.915	0.892	0.864
Raw Coverage	0.342	0.385	0.284
Unique Coverage	0.112	0.156	0.095

Legend: ● = Core condition present (Strong causal relationship); · = Peripheral condition present (Contributing factor); ⊗ = Core condition absent; ◦ = Peripheral condition absent; Blank = "Don't care" (Condition may be present or absent). Overall Solution Consistency = 0.884; Overall Solution Coverage = 0.782.

Causal Asymmetry: In an attempt to check the assumption of causal asymmetry, we also studied path analysis leading to low work engagement. The results indicated that the root reasons for low engagement were certainly not just missing any of these conditions, but rather a unique "toxic brew," which we term as low system responsiveness x acoustic control. So while a hospital can control the furniture in their break room and provide seating that is purported to be ergonomically good, if things are too loud or computers don't work right, nurses will still burn out.

IV. DISCUSSION

In this respect, we triangulated PLS-SEM with ANN and fsQCA as validation procedures to uncover the complex nonlinear effects of intelligent nursing environment on nurses' occupational well-being. Through the empirical results, it not only verifies that the SEIPS model is applicable to nursing wards but also challenges its traditional inertia: "to emphasize hard facilities and ignore interaction", complementing each other with multidimensional data. It is exactly the kind of level-headed, evidence-based backing that will help grow and establish "smart nursing pods."

The inhibitory effect of physical environment over occupational burnout, in comparison to technical Tools & Tech), was relatively much greater ($\beta = -0.456$) using PLS-SEM path analysis.This is in line with environmental psychology generally, which believes that space functions not only as a container but also as an adjuster of psychological aspects. Nonetheless, a nonlinear importance ranking from ANN yields an unexpected result: the single usability measure "system response speed (TT_Res)" scores highest with 100% normalized importances and outranks all physical artifacts. This result is highly trivial and thus we may unknowingly misinterpret it as a typical software engineering issue, which seems to fall out of domain limited in true environmental design research. This study however claims that this exact finding reveals a fundamental deficiency in contemporary hospital construction — the hardware-software mismatch—when the physical environment has not effectively created "infrastructural redundancy" for critical digital systems under high load. In terms of the SEIPS model, but technical tools are not abstract; they exist as tangible objects located within an environment. Environmental psychology theorizes that a space is not merely the container of psychological resources but it also regulates them; and when considering how these spaces manifest occupationally, occupational burnout remains an area to be fully explored.

Hence, in line with the PLS-SEM path analysis of the study, physical environment has a broader inhibitory effect on burnout compared to technical tools [21]. Moreover, a Nerve Net (ANN) further shows that the "reaction response of system" as an important nonlinear factor affecting occupational wellbeing exposes deficiency in hardware – software medley during hospital construction. Prior research on the effects of digital readiness for organizational incrementation with software solutions often stresses that hardware systems play a crucial role, which involves the physical rooting or embedding of technical tools in an environment [25]. However, for the new definition of physical attributes in intelligent nursing environment such as visual ergonomics and light environment control solutions can effectively mitigate the excessive cognitive load represented by screen glare so that nurses cannot feel "sluggish system responses". Finally, the problem of wireless signal attenuation within multi-layered building walls was discussed and a Signal LOS Analysis to enhance network connectivity through connection "friction reduction" were suggested as practical design strategies. Additionally, convenient and optimized power layouts minimize device low-battery anxiety and lower cognitive load which is in line with the turn of well-being for optimal occupational design [22].

A. The "Threshold of Silence": Non-linear Effects of Acoustics

The second main proximate result reported by the ANN analyses was the clear anterior-only threshold effect of PE_Noi, giving more practical guidance for evidence-based design than would be possible from linear regression. This vanishing variance ratio of PLS-SEM (0.456) implies that no matter how much resources we spend, silence is our only linear logic — the more invested efforts the better;. Nonetheless, the ANN prediction curve unravels the law of diminishing marginal returns: as can be observed from data, when noise interference evaluation moves upward to score 4.0 (corresponding "relatively quiet" background noise level ≈ 45dB), occupational burnout trajectory flattens. For example, in our ANN model the benefit of reducing noise from 45 dB to say studio recording levels (35dB) as far as nurses' occupational well-being is concerned has a negligible predicted outcome and it requires significant investment on architectural acoustics industrial practice like triple glazed windows and floating floors.

Theoretical and practical significance:This nonlinear finding counters the prevailing belief in conventional EBD research that more is better, offering an ethic of good enough design. For general wards in resource-limited public hospitals, the goal of design should not be world-class acoustic metrics but to accurately identify and target 'acoustic pain points' that fall below a rating 3.5. As our results underestimated the optimal designs to some extent, this threshold-based design strategy can assist hospital administrators to gain most of well-being benefits within limited budget and prevent inefficiency arising from over-design.

B. Design Archetypes: Context-Aware Configurations

1) Archetype A: Core requirements, respond and keep up rate of system throughout high-level response maintainability The "High-Performance Crew: High performance cockpit." Intriguingly, this is a dispensable step for " atmosphere creation. Type of healthcare facility: Strategy for acute departments like surgery or emergency. The Wraparound Cockpit Layout comes with up to 3 screens and reduces body twist movements also eye movement paralysis while multi-screen interaction, the design enables adaptation in ergonomics for it. Workstations need to shift out of decorating demand, optimize "zero-delay operation" and "ultimate efficiency," build a digital command fortress for nurses.

2) *Archetype B:* The "Bio-restorative Pod":The core requirements are a low level of acoustic, plenty of rest space and ambient sound. Design Strategy: Appropriate for internal medicine or palliative care settings. So, this is what the "Smart Quiet Pod" would look like. The design is centered around a " Sensory Refuge. They include circadian lighting, and natural soundscapes (eg white noise), essentially Reduce ward based visual & auditory stimuli physically masking them.Reinstating powerful psychological healing functions.

3) Archetype C: The "Process-Wall": The Process-Integration Model (SEIPS-based Organizational Intervention). Targeted at resource-limited primary hospitals, this model shifts focus from expensive hardware to process optimization. 1. Physical Strategy: Utilizing cost-effective physical partitions (e.g., smart glass or distinct floor marking) to delineate "boundary zones" for shift handovers. 2. Organizational Strategy (The Missing Link): Implementing a "No-Interruption Zone" protocol during peak handover times (08:00–09:00). This involves an organizational policy where non-emergency calls are automatically routed to a covering "float nurse," ensuring the handover team faces zero digital interruptions. 3. Process Strategy: Standardizing the "Digital Huddle" workflow, where the sequence of information on the digital display board strictly mirrors the verbal SBAR (Situation, Background, Assessment, Recommendation) checklist, reducing the cognitive friction of searching for data during communication[3].

C. Limitations and Future Directions

Despite employing multiple validation methods, this study still has the following limitations: First, while cross-sectional data can reveal correlations, it is somewhat weak in inferring strict causal relationships. Future research could adopt a longitudinal design, collecting data before and after hospital renovations to verify the actual effects of design interventions. Second, the data in this study mainly comes from Class A tertiary hospitals in China, whose high-intensity work patterns may limit the generalizability of the conclusions to private hospitals or low-density healthcare environments in Europe and the United States. Finally, although the ANN captured nonlinear relationships, the current model is primarily based on nurses' subjective perception data. Future research could integrate physiological stress data collected by wearable devices (such as galvanic skin response sensors), as well as real-time noise/illumination data recorded by environmental sensors, in order to achieve multimodal fusion analysis of both subjective and objective data.

V. Conclusion

A. Synthesis of Triangulated Evidence

This study is one of the first empirical attempts to decode the "black box" of nurse well-being in smart care environments through methodological triangulation using partial least squares structural equation modeling, ANN, and fuzzy-set qualitative comparative analysis. By moving beyond the limitations of traditional linear regression, we reveal the complex, nonlinear, and asymmetric mechanisms that govern the interplay between physical space and digital workflows. In addition to the above, focusing on "system response speed" as a significant stressor and an essential underlying reason for possibly observing a " tolerance cliff " an ANN model can outperform traditional linear models owing both quantitatively and theoretically this has been further demonstrated. As in the case of ANN, it highlights hidden hierarchical relationships across variables and threshold effects [8] , while capturing higher-order interactions that deliver more precise learning as well. In terms of fatigue in the case that SL friction is not well distinguished, the frequency-dependent law also has similarities to a phenomenon known as " diminishing returns " and approach an exhausted threshold like diminishing marginal utility regarding resource allocation [9], proposing early key design investments targeting elements with much return on real useful effort; so it must be consider NaN in such systems. This tells us that what staff might just perceive as a "slow computer" is in fact recognised by nursing, being more accurately viewed as an environmental failure to deliver care. The other important economic insight in acoustic cues is the "diminishing returns curve" for control: While zero noise may be perfect, getting to studio-level silence only matters so much when you should have already been more focused on dispensing with digital friction.

B. Theoretical Implications: From "Form Follows Function" to "Form Follows Friction"

This study introduces the " Form Follows Friction " design mentality that continues to explore the new function of Physical Environment as a " Cognitive Exoskeleton " , leading to decreased occupational burnout by reducing cognitive loads on engaging technology interactions. This hypothesis is similar to the current research in user experience and service design [26][27] , which highlights that creation should synchronize with cognitive load of the user + interaction friction experienced between human digital environments. At the same time, fsQCA is able to accommodate that principle of multi-path success in complex configurations and realizes a multiplicity of conditions and contexts comes into play during design decision-making[9][28].Therefore, the "Form Follows Friction" paradigm requires that each physical design decision—from the curvature of nursing stations to the choice of ceiling materials— be evaluated by a new criterion: does this design element reduce the cognitive cost of human-computer interaction?

C. Managerial and Practical Implications

The concept of "shifting from standardization to configurational thinking" proposed in this study aligns with the causal mechanisms involving multiple pathways and configurations revealed by fuzzy-set qualitative comparative analysis (fsQCA). Related literature shows that fsQCA is widely used to uncover the interactive relationships among multiple factors and multiple paths to success in complex systems, such as multi-condition collaborative innovation paths in enterprise digital transformation[28], multiple conditional combinations for the successful implementation of shared service centers[25], and the configurational effects of AI ethics and trust on professionals' perceived responsibility in healthcare[29]. These studies support the view that there is no single "gold standard" for smart wards, and a multi-configurational perspective should be adopted in their design and implementation[30]. The notion of "infrastructure as care" highlights the importance of invisible infrastructure for nurses' well-being, echoing the emphasis in the literature on the significance of digital infrastructure and hardware systems. In a related vein, digital transformation invisible resources in edge computing nodes or high performance cabling and environmental lighting underline system performance: they also impinge upon user experience [3]. As the data are interpreted, so this reminds those looking at improvements that ignoring physical support very quickly leads to high stress in staff (the " tolerance cliff" noted), thus consistent with recognition of intertwined between the service environment and technical facilityolución en forma. The economic concept of " satisficing " applies to the use of artificial neural networks (ANN) for identifying threshold effects, supporting our view on targeted investments over equal opportunities that in sum add cost and waste. This same sort of configural thinking is seen in business resource allocations and innovation investments. From the literature this phenomenon of threshold effect, or a kind of " critical point " was described as that at some resources level their marginal benefit will no longer be positive suggesting to choose and from then on investing particularly in critical pathways [3]. Context-aware design is designed on a departmental level and by assignment conforms to the ideas of configuration theory.As an example, surgical wards demand zero-delay information flow and are supplied a large " cockpit" from which to orchestrate care whereas palliative beds resemble the design of monastic cells distinguishing between strategies that pertain specifically to processing friction as functional units. These include personalized configurations found in logistics management as well, and the introduction of a notion of AI accountability to healthcare[28]. In short, relevant research evidence generally confirms that as healthcare is " digitized," so too comes the friction of a "digital patient experience." The solution lies not in simply avoiding technology but in redesigning the physical environment to achieve symbiosis between digital systems and spatial environments, thereby improving overall care quality and nurses well-being. This friction-reducing design philosophy effectively integrates the interaction of technology and environment, emphasizing the reconstruction of humanity within medical practice by prioritizing a caring, high-touch environment[3][29].

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