MCDM-Based Design Decision-Making for Feeding Assistive Technology in Neurodegenerative Diseases: A Case Study of Parkinson's Disease

1st Jingting Cao
School of Architecture and Design
Nanchang University
Nanchang, China
caojingting@email.ncu.edu.cn

2nd Changdong Lin
School of Architecture and Design
Nanchang University
Nanchang, China
linchangdong@email.ncu.edu.cn

3rd Zhaoqing Li
School of Architecture and Design
Nanchang University
Nanchang, China
lizhaoqing@email.ncu.edu.cn

4th Rui Wang*
School of Architecture and Design
Nanchang University
Nanchang, China
awangrui@ncu.edu.cn

***Abstract*—Although a considerable engineering investment in Parkinson's disease (PD) auxiliary technology, this current solution still faces an endless paradox: "high-tech funds raised high), it is difficult to be universal". The main reason for this failure is the sheer imbalance and focus placed on preventing essential physiological tremor while completely ignoring psychosocial requirements. To solve the mystery of "black box" in design decision-making, a new hybrid multi-standard decision-making (MCDM) framework has been proposed by combining system review (PRISMA), Carnot model and analytical hierarchy process (AHP). Fifteen design factors are synthesized through the interdisciplinary literature review guided by PRISMA. Kano questionnaire and rankinga of the demand attribute from 24 PD patients was evaluated by AHPb from 24 experts to establish a global weight. Three important insights are uncovered by the study: (1) Reaffirming the Physiological Foundation: Active stabilization (F1, w=0.149) retains its status as the most significant attribute, confirming that functional tremor suppression remains the non-negotiable priority; (2) Dignity as a Baseline: Invisible/de-medicalized aesthetics (F13, w=0.064) was classified as a 'Must-be' attribute rather than a value-add, validating that destigmatization is a prerequisite for adoption; (3) Emergence of Intelligence: Tremor data monitoring (F11, w=0.095), previously considered a "value liability", unexpectedly ranked third, marking a shift towards data-driven disease management. Therefore, the article suggests "Safety & Dignity (Foundation) – Intelligence (Engine)" as a hierarchical design strategy set. From these findings, it is proposed that the next generation of assistive technologies should shift from a "prosthetics for limb" paradigm to "guardians of self", wherein technology and humanity are jointly optimized through quantified humanistic care.**

Keywords—Parkinson ' s Disease; Feeding Assistive Technology; Multi-Criteria Decision Making (MCDM); Kano Model; Analytic Hierarchy Process (AHP); Design for Dignity; Sociotechnical Systems.

I. INTRODUCTION

From an overall perspective developing steady neurodegenerative disease, Parkinson's Disease (PD) is fastest growing which plays a fundamental part in changing wellbeing sign of age people. By 2040, it is expected that the worldwide PD population will approach or exceed twelve million [1]. Cardinal motor symptoms such as tremor, rigidity and bradykinesia [2] preconditioned eating behavior - a fundamental human right and social activity nowadays to be the center of daily adversity.

A. Background: From Physiological Dilemmas to Psychosocial Challenges

Over the last ten years, resources from within the engineering community had been poured into addressing a PD symptom known as "eating tremor". Technical intervention has come a long way from early passive damping handles to active stabilisation spoons based on microelectromechanical systems (MEMS) (Liftware, Gyenno) [3]. These "techno-centric" solutions predominantly adhere to the biomedical model, striving to neutralize pathological tremors through mechanical means.

Yet, as ever stark clinical reality testifies to (4), the daunting "abandonment paradox" ruthlessly endures this ineffable robust laboratory performance; contrary to overwhelming evidence base from such studies of superior efficacy done in an ideal sterility approximating environment designed outside real-world and electronic-equipment accustomed hospital life longevity patient care scenarios – a cardiac high-tech auxiliary equipment remains disposed at clinically not infrequent rate even if capping 100% long-term dawn-end natural free follow-up lives! Even with ubiquitous smart equipment, a large number of patients still choose to give up expensive fixed monitoring devices because they feel "Very bad".[4] in early studies reported an abandonment rate of 30% ~50%, and one survey further confirmed it.[5], [6]. This indicates that design efficiency has topped out at mere physiological function compensation, which is not enough to bridge the crucial gap between standardised clinical verification and domestic adoption multitasking reality.

So why did such a powerful piece of hardware get left on the shelf? That is the main reason, because eating does not equal absorbing nutrients. In our society it also means performing a kind of social expression . The stigmatisation theory by Goffman [7] suggests that when a person has certain 'unique' characteristics or attributes, they are more likely to have their social identity impaired. Traditional assistive technology typically takes the form of an awkward mechanical device that not only harshly reminds people they are disabled, but it also stands out to others. The "disability amplifier" as some have classified this at the public table [8]. While voluntary tremor might be mechnically concealed, the patients are left to face their profound psychological "spolight effect" and social embarassment: they will often stop going out for a meal just so that can maintain what little dignity is available.

*Corresponding author:Rui Wang;School of Architecture and Design, Nanchang University; Nanchang,China; awangrui@ncu.edu.cn

Furthermore, the present of design is often not designed to include this 'invisible work' in the home care system [9]. The complex electronic stabilization structures need recharging, firmware updates and must maintain the hard-to-clean up sanitary blind spots. For example, a device that requires too much mental and physical resources to “repair equipment” will result in ‘value mismatch’ which means the family ecosystem gets rid of it [10].

B. The "Black Box" of Current Design Decision-Making

This disciplinarily isolated condition contrast sharply with the moral plaza where several forms of social production and media technologies are intertwined. Engineering paper mainly discusses the optimization of control algorithms, but also "hardness" (such as amplitude attenuation in dB) is a single evaluation standard. Conversely, although researchers in the human-computer interaction (HCI) and design sociology have identified ‘empowered’ patients [11], a score for empowerment quanta of this concept to phase into the engineering development workflow is absent. Thus, at the stage of specification writing all too many psychosocial insights get summarily dismissed as "alleged anecdotal information".

As a result, the qualitative vs quantitative approaches dichism tends to create this "black box" in which we rely upon design decision-making. If engineers come up against the fundamental "performance-impedance tradeoff"—for example, whether to boost battery size so a device can be more stable (improve performance) or shrink its footprint so users feel less stigmatized by it (reduce invasiveness)—the absence of explicit and implementable rules for how to balance these competing imperatives typically results in building devices that are technically potent but socially incompatible. Besides, the current assistive technology evaluation model (e. g., QUEST 2.0) can be utilized merely as a “post-evaluation” procedure after product development and there is no “pre-decision-making" model that could integrate multiple needs dimensions at an early stage of design process.

C. Research Objectives & Framework

This raises the question of how to reveal a model for "pre-decision-making" with respect to recent auxiliary technology design that can increase precision and efficiency thereby guiding optimal development resource allocation. New site-specific perspective of this study is that for the first time we propose both “burden to caregivers” and “dignity,” dividing them into the standard layer of decision making model in order to account humanistic nursing as a core position inside assistive technology system by using rigorous mathematical language (weight & priority). This methodology elegantly reconciles social science values with engineering parameters.

The technical route of this study follows a strict "Input-Process-Output" logic, as illustrated in Fig. 1:

- IInput: factors for a system literature review are synthesized from the interdisciplinary metadata, and;THE PRISMA declaration is met.
- Process: A hybrid Kano-AHP model was developed. The Kano model is intended to demonstrate the nonlinear nature of user perception attributes, while analysis hierarchy process (AHP) estimates global weights in order to facilitate quantitative quantification of objective parameters and subjective experience.
- Output: Visualize a “strategic mapping matrix”— classifying the design factors into ”health factors”, growth engine and value liabilities.

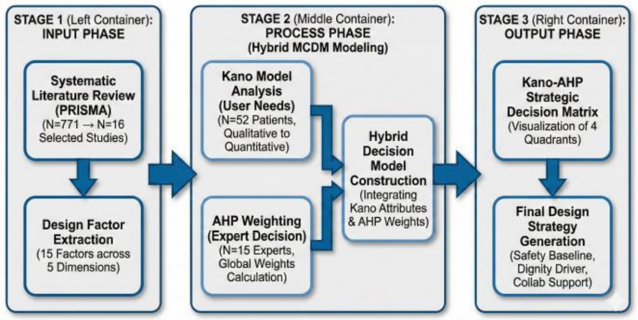

Fig. 1. Technical Roadmap of the Research Framework. The process follows an Input-Process-Output logic.

II. METHODOLOGY

Here in this study, we proposed a novel hybrid multi-standard decision-making (MCDM) framework by integrating PRISMA systematically literature review protocol, Kano model and analytical hierarchy process (AHP). This work aims to address the decision-making dilemma "glaring functional indicators and hidden emotional needs" in auxiliary equipment design for neurodegenerative diseases.

A. Data Sourcing via PRISMA

To guarantee both the completeness and empirical validity of design decision-making factors, our study follows the guidelines given in PRISMA 2020 statement and incorporates designs from a multidisciplinary database.

The literature retrieval was completed on January 3, 2026. Given the intersectional nature of Parkinson's disease assistive design involving medicine, engineering, and sociology, four core databases were selected: Web of Science, Scopus, PubMed, and IEEE Xplore. The search logic adopted the "Population (P) + Intervention (I) + Outcome (O)" framework. The keyword combination was set as: ("Parkinson's disease" OR "Tremor") AND ("Eating" OR "Feeding") AND ("Assistive technology" OR "Design strategy") .The time span was limited to the period from 2010 to 2025.

The initial comprehensive search yielded a total of 771 records. To ensure the quality of the final design factor pool, a rigorous multi-stage screening process was implemented. First, duplicate removal via EndNote excluded 78 records. Subsequently, a preliminary screening of titles and abstracts was conducted to eliminate 676 non-specific studies that focused solely on pharmacological treatments or lacked design-related data. Finally, 17 full-text articles were assessed in detail for eligibility. Ultimately, 16 high-quality empirical studies met all inclusion criteria and were selected to construct the foundational pool of design factors. The detailed flow of this screening process is illustrated in Fig. 2.

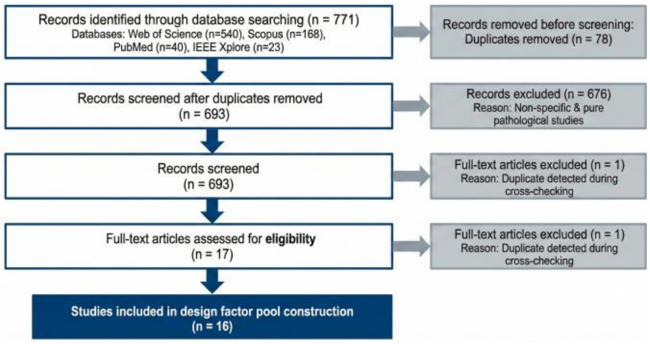

Fig. 2. PRISMA Flow Diagram of Literature Selection Process.

To transform heterogeneous evidentiary data into quantifiable decision metrics, Thematic Analysis was employed to establish a "Source-Coding-Factor" translation matrix. This process extracted 15 key design factors, categorized into five dimensions (see Table 1).Attribute Categorization via Kano

TABLE I. MATRIX (BASED ON N = 16 STUDIES)

Dimension	Source Evidence	Coding	Design Factor
D1:*Physiological*	"Reduces tremor amplitude via active mechanism" [12],[13]	Active tremor cancellation	F1: Active Stabilization
	"Passive vibration absorber... no electronics" [14]	Passive mechanical damping	F2: Passive Damping
	"Calculated flow rate to prevent aspiration" [15]	Fluid flow regulation	F3: Fluid Flow Control
	"Nosey cup design allowing safe swallowing angle" [15]	Safe swallowing posture	F4: Safe Swallowing Geometry
D2: *Ergonomics*	"High friction handle for better grip" [16]	Friction enhancement	F5: High-Friction Grip
	"Vertical grip to assist users with hand rigidity" [17]	Vertical power grasp	F6: Vertical Power Grip
	"Weighted handles... improves proprioception" [18]	Proprioceptive weighting	F7: Weighted Handle
D3: *System Efficacy*	"Does not require external energy" [14]	No charging/maintenance	F8: Battery-free Operation
	"3D printed... low cost fabrication" [19],[17]	Low-threshold access	F9: Low-Cost/DIY Accessibility
	"Ease of cleaning and maintenance" [20]	Sanitation efficiency	F10: Hygiene Efficiency
D4: *Intelligence*	"Monitors tremor data... diagnostic assistive" [21]	Data monitoring/logging	F11: Tremor Monitoring
	"Auto-calibration based on user's tremor pattern" [21]	Algorithmic adaptation	F12: Adaptive Algorithm
D5:*Psychosocial*	"Designs that look like mainstream products" [6]	Demedicalized appearance	F13: Discreet/Mainstream Aesthetics
	"Participants felt less embarrassed" [22]	Stigma reduction	F14: Low Social Stigma Design
	"One handle for writing and eating" [17]	Cross-scenario integration	F15: Modular Multi-functionality

Following factor extraction, the Kano model was introduced to reveal the nonlinear mechanisms by which each factor influences user satisfaction.

- IQuestionnaire Design: According to Norman's theory of "psychological model matching" [23], the abstract technical parameters shall be mapped into everyday situations known by patients (see Table 2) in order to reduce elderly subjects' cognitive load. We employ a 5-point Lickert scale questionnaire. Data Collection: Given that PD patients may experience cognitive decline, strict screening criteria were implemented: confirmed PD diagnosis (Hoehn & Yahr stages 1 – 3) and an MMSE score . Questionnaires were distributed via online communities and offline hospitals, with a target of at least 50 valid responses.
- Classification Metrics: Attributes were classified based on the Kano evaluation table, and "Better-Worse" coefficients were introduced to analyze sensitivity. The calculation formulas are as follows:

$$Better(SI) = \frac{A + O}{A + O + M + I} \quad (1)$$

$$Worse(DDI) = (-1) \times \frac{O + M}{A + O + M + I} \quad (2)$$

Where A represents Attractive attributes, O One-dimensional attributes, M Must-be attributes, and I Indifferent attributes. These two coefficients served as the abscissa input for the subsequent decision matrix [24].

B. *Weighting via AHP*

To quantify resource allocation priorities, the Analytic Hierarchy Process (AHP) was introduced [25].

1) Hierarchical Structure: Based on Sociotechnical Systems (STS) theory, a three-layer "Goal-Criteria-Alternatives" model was constructed (see Fig. 3) [26]. The criteria layer includes: B1 Physiological Functionality (Technical Subsystem), B2 Emotion & Dignity (Social Subsystem - Patient), B3 Collaboration Efficiency (Invisible Work), and B4 Economy & Accessibility.

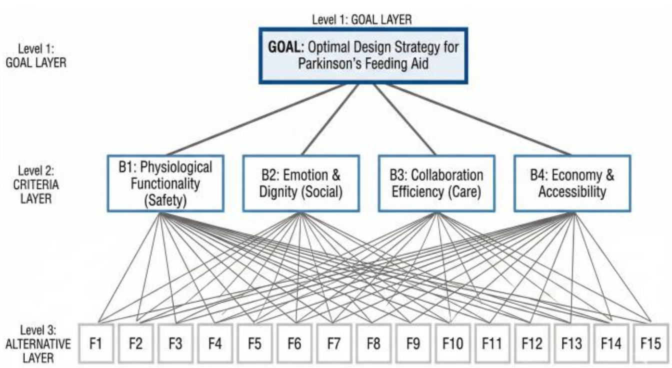

Fig. 3. Hierarchical Structure of Parkinson ' s Feeding Aid Design Decision

TABLE II. OPERATIONALIZATION OF KANO QUESTIONNAIRE DESIGN FACTORS (SELECTED)

Factor	Functional Question (Positive)	Dysfunctional Question (Negative)	Translation Logic
F3: Fluid Control	If the cup automatically limits flow rate to prevent choking, how do you feel?	If the cup flow is fast and causes choking, how do you feel?	Safety Projection: Translating hydrodynamics into "anti-choking" safety.

Factor	Functional Question (Positive)	Dysfunctional Question (Negative)	Translation Logic
F1: Active Stabilization	If the spoon automatically cancels out your hand tremor, how do you feel?	If the spoon shakes with your hand and spills food, how do you feel?	Direct Function: Assessing the core value of tremor cancellation.
F13: Discreet Aesthetics	If the spoon looks exactly like normal tableware used by others, how do you feel?	If the spoon looks like a medical device and attracts attention, how do you feel?	Social Integration: Converting "stealth design" into "de-labeling" needs.
F15: Modular Function	If one handle can switch between spoon, pen, and toothbrush heads, how do you feel?	If you need separate specialized tools for eating, writing, and brushing, how do you feel?	Life Simplification: Testing the acceptance of integrated lifestyle tools.
F11: Tremor Data	If the device records tremor data for your doctor, how do you feel?	If the device has no recording function, how do you feel?	Reverse Detection: Probing if monitoring causes "disease fatigue".
F9: Low Cost/DIY	If you can print the parts cheaply at a local store, how do you feel?	If you can only buy expensive replacements from hospitals, how do you feel?	Accessibility: Measuring the appeal of distributed manufacturing.

2) Expert Panel: The decision-making panel consisted of 24 senior experts (19 Neurologists, 4 Designers, 1 Nurse), with an average professional experience of 18.5 $\pm$ 8.9 years (see Table 3).

TABLE III. DEMOGRAPHIC PROFILE OF THE EXPERT PANEL (N = 24)

Group	Domain	N	Years of Exp.	Selection Criteria
G1	Neurology / Rehab Medicine	19	Avg. 18.5	Senior/Associate Chief Physician; extensive clinical experience in PD.
G2	Industrial Design / Human Factors	4	Avg. 9.0	Professors/Senior Designers led medical aid R&D projects.
G3	Clinical Nursing / Home Care	1	>10	Senior PD Nurse Specialist with frontline care insights.

3) Weight Calculation: The Saaty 1–9 scale was used to construct the judgment matrix, and the Consistency Ratio (CR) was calculated. First, the Consistency Index (CI) was computed:

$$CI = \frac{\lambda\, max - n}{n - 1} \quad (3)$$

Subsequently, the Consistency Ratio (CR) was calculated:

$$CR = \frac{CI}{RI} \quad (4)$$

Where $\lambda_{max}$is the maximum eigenvalue, n is the matrix order, and RI is the Random Consistency Index. When $CR < 0.1$, the matrix is judged as valid, and the geometric mean method is used to aggregate group decision weights [27].

C. Strategy Generation Rules

To generate actionable guidelines, a "Kano-AHP Strategy Mapping Matrix" was constructed. The vertical axis represents the AHP Global Weight (α), and the horizontal axis represents the Kano sensitivity coefficient. Three core decision rules were formulated:

- DR1 (Red Line Rule): If a factor is a Must-be attribute and its weight exceeds the threshold (α), it is defined as a "Survival Cornerstone" and must be unconditionally satisfied.
- DR2 (Value Driver Rule): If a factor is an Attractive attribute with high weight, it is defined as a "Dignity Driver" and serves as the core for differentiated competition.
- DR3 (Pruning Rule): If a factor is an Indifferent attribute or has excessively low weight, it falls into the "Waste Zone" and should be eliminated or kept as a technical reserve.

D. Integrated Weight Calculation

To accurately translate the qualitative Kano categorization into quantitative decision weights, this study employs a Priority Adjustment Coefficient (k).

1) User Impact Quantification: Based on the Satisfaction Coefficient (Si) and Dissatisfaction Coefficient (Di) calculated in Section II-A, we synthesized the overall influence of each design factor. A Vector Magnitude (ki) was defined to measure the geometric distance from the origin on the Kano evaluation plot. A larger ki indicates that the factor has a stronger impact on user experience:

$$k_i = \sqrt{(S_i)^2 + (D_i)^2} \quad (5)$$

2) Global Weight Synthesis: Finally, the Global Weight (W_g) was calculated by integrating the expert perspective with user priorities. The AHP weight (w_j derived from the expert panel (calculated in Section II-B) serves as the functional baseline, which is then dynamically adjusted by the user-derived Kano magnitude (ki). The normalization formula is as follows:

$$W_g = \frac{w_j \cdot k_i}{\sum_{j=1}^{n} (w_j \cdot k_i)} \quad (6)$$

Through this mathematical integration, the final ranking prioritizes features that are not only technically essential (high AHP weight) but also psychologically critical to patients (high Kano magnitude).

III. RESULTS

This section presents the data analysis results based on the hybrid "PRISMA-Kano-AHP" model. First, the Kano questionnaire revealed the qualitative preferences of users for 15 design factors; second, the AHP expert group decision-making process computed the quantitative weights of evaluation criteria; finally, the two were synthesized to construct a visual strategic decision matrix.

A. Kano Classification & User Preferences

A total of 70 Kano questionnaires were distributed Following strict screening for H&Y stages 1-3 and MMSE $\geq$ 24, 24 high-quality valid responses were included in the final analysis. The demographic profile... with an average age of 64.7 $\pm$ 6.7 years (54.2% Male). Based on the Kano attribute classification table and the Better-Worse sensitivity coefficients, the detailed classification results and attribute definitions for the 15 design factors are integrated into Table 5. The results show significant attribute differentiation:

- Must-be Attributes (M): Four items, concentrated in the dimension of physiological safety. The absolute values of the Worse coefficients () for F3 (Fluid Flow Control) and F1 (Active Stabilization) reached 0.865, validating that "swallowing safety" and "tremor stabilization" constitute the baseline requirements of the product.
- Attractive Attributes (A): Seven items. Secondly, F13 (cautious aesthetics) and F14 (de-stigmatising interaction) are also significantly more attractive at a psychosocial level. This, in turn means that just because users do NOT need to be 'de-labelled' - like seen before: if you realise it though the satisfaction will increase exponentially.
- Indifferent Attributes (I): The most notable finding concerns F11 (Tremor Monitoring). Although technical literature regards it as a core innovation, it was categorized as an Indifferent attribute () on the patient side, with 17.3% of users even judging it as a Reverse attribute.

B. *AHP Weight Distribution & Comparison*

Based on the judgment matrices constructed by 15 interdisciplinary experts, the weights of indicators at each layer were calculated. In all judgment matrices, CR (Consistency Ratio) were less than 0.1(G.D.M; Group Decision Matrix $CR = 0.002$).

Criteria Layer Analysis: As shown in Table 4, the weight of B1 Physiological Functionality (0.419) holds a dominant position, followed by B2 Emotion & Dignity (0.267) and B3 Collaboration Efficiency (0.239). This distribution reaffirms that while psychosocial factors are critical, experts still regard the fundamental mechanical resolution of tremor as the primary therapeutic prerequisite. Notably, the close proximity of B2 and B3 suggests that in the experts' view, "maintaining self-identity" and "system efficiency" are equally vital pillars supporting the physiological core.

TABLE IV. WEIGHTS OF CRITERIA LAYER ($CR = 0.071$)

Criterion	Weight	Rank	Interpretation
B1 Physiological Functionality	0.4193	1	Physical foundation ensuring eating safety and efficiency
B2 Emotion & Dignity	0.2670	2	Key Finding: Dignity weight significantly elevated
B3 Collaboration Efficiency	0.2385	3	Addressing caregiver burden and invisible work
B4 Economy & Accessibility	0.0752	4	Cost concerns, but not the primary decision factor

1) Global Factor Ranking: A mapping between the 15 factors, which are derived by aggregating both items in a single layer of subjective logics (e.g., alternative layers with standard only), and their corresponding Kano property is shown as Table 5. Three harmful signals emerged from the data:

- Physiological Foundation:F1 Active Stabilization ($W_g = 0.149$) topped the list (Rank 1), confirming that mechanical tremor suppression remains the core hygiene factor.
- Dignity as Baseline: F13 (Discreet Aesthetics) ranked 7th ($W_g = 0.064$) but was classified as a 'Must-be' attribute in the Kano model. This indicates that while physiological function (F1) remains the primary driver, destigmatization is no longer a 'value-added' feature but a basic qualification for market entry. Unlike the "techno-centric" view where aesthetics are optional, this finding establishes that lacking dignity features acts as a veto factor for device adoption.
- Digital Empowerment: Contrary to previous assumptions, F11 (Tremor Monitoring) ranked 3rd ($W_g = 0.095$) and was identified as a 'Must-be' attribute. This suggests a paradigm shift where patients actively seek data-driven insights to manage their condition, moving beyond passive assistance to active health monitoring. This result refutes the hypothesis that monitoring creates "cognitive burden," instead proving that patients value quantified self-management as a core safety net.

From hard data to strategyIn order to convert the complex data into an easily understood strategies a "Parkinson's Feeding Aid Design Strategy Matrix" was developed (Fig. 4).

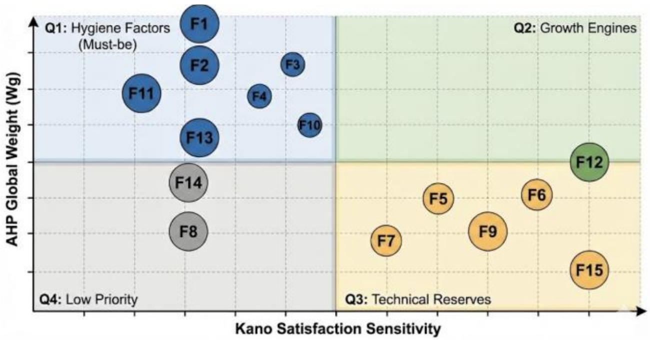

Fig. 4. The Kano-AHP Strategic Decision Matrix Visualization.

Factor design shows clear strategic stratification from the matrix positioning:

- Q1 Survival Cornerstone (Hygiene Factors): high weightage and must-have properties. F3, F4 and F1 is the space where we reside in defining safety "passing line" that needs to be standardised.
- Q2 Growth Engine (Dignity Drivers): High Weight + Good Lookingqualities. Both F13 and F15 live here. This is the central trajectory with which this study can identify in terms of core strategic opportunity—moving design value from 'physiological compensation' to possilbe psychological empowerment horizon.

TABLE V. INTEGRATED RESULTS: RANKING, KANO CLASSIFICATION AND STRATEGY MAPPING

Rank	Code	Factor Name	Dimension	Kano Class	Global Weight (W_g)	Strategy Quadrant
1	F1	Active Stabilization	Function	M	0.149	Q1: Hygiene
2	F2	Passive Damping	Function	I	0.118	Q3: Reserve
3	F11	Tremor Monitoring	Intelligence	M	0.095	Q1: Hygiene

Rank	Code	Factor Name	Dimension	Kano Class	Global Weight (W_g)	Strategy Quadrant
4	F3	Fluid Flow Control	Safety	M	0.083	Q1: Hygiene
5	F4	Safe Swallowing Geometry	Safety	M	0.070	Q1: Hygiene
6	F10	Hygiene Efficiency	Collab	M	0.066	Q1: Hygiene
7	F13	Discreet Aesthetics	Dignity	M	0.064	Q1: Hygiene
8	F5	High-Friction Grip	Ergonomics	M	0.055	Q1: Hygiene
9	F12	Adaptive Algorithm	Intelligence	O	0.054	Q2: Driver
10	F14	Destigmatizing Interaction	Dignity	M	0.051	Q1: Hygiene
11	F6	Vertical Power Grip	Ergonomics	M	0.050	Q1: Hygiene
12	F7	Weighted Handle	Ergonomics	M	0.047	Q1: Hygiene
13	F8	Battery-free Operation	System	M	0.042	Q3: Reserve
14	F9	Low Acquisition Cost	Economy	O	0.033	Q3: Reserve
15	F15	Modular Functionality	Collab	M	0.024	Q3: Reserve

- Q3 Technical Reserve (Nice-to-have): not heavy+between the lines. F12 belongs to this area. So it should be used as a high level optional (not common standard).
- Q4 Waste Zone: In this empirical study, no major factors fell into the strict 'Waste Zone'. Factors like F2 (Passive Damping) ($W_g = 0.118$, Indifferent) are better categorized as Technical Reserves rather than pure waste, suggesting they may serve as low-cost alternatives or safety nets, even if they do not directly drive satisfaction.

So in conclusion the decision making matrix sets a new design paradigm: "security as grounding (Q1), dignity as motive force (Q2) and simplicity is just tool to get rid of Q4."

IV. DISCUSSION & DESIGN STRATEGY

This chapter compiles the 15 design factors into three fundamental strategic paradigms that are identified through quantitative analysis based on Kano-AHP decision making matrix. Building on the theoretical foundations of the Social Technology System (STS) Theory, we investigated in depth how these strategies meet Parkinson patients' complex needs.

A. The Hygiene Factors: Safety & Physiological Compensation

Factors located in the first quadrant (Q1) (F3, F4, F1, F10) are defined as "Hygiene Factors." Under the STS framework, they constitute the "Technical Subsystem." Following the principle of "Joint Optimization," the social subsystem (patient dignity) possesses a foundation for construction only when the technical subsystem is sufficiently robust.

1) Reaffirming the Physiological Foundation: F1 (Active Stabilization) secured the top spot($W_g = 0.149$) , classified as a 'Must-be' attribute. This confirms that despite the emphasis on holistic care, the mechanical suppression of tremor remains the fundamental hygiene factor that directly determines the usability of the device. This data forcefully corrects the design community's deviation of over-focusing on "hand tremor" while neglecting "oropharyngeal dysphagia." Over 80% of PD patients experience dysphagia [15], and aspiration pneumonia is a leading cause of death [28]. Therefore, the primary task of the foundational strategy is to establish the principle of "Swallowing Safety Priority" [29]:

- Fluid Dynamics Control: The cup body should incorporate a flow restriction valve to limit liquid velocity within a safe threshold (e.g. ＜10ml/s）, physically blocking the risk of choking.
- Chin-tuck Support: The high weight of F4 validates the necessity of the "nosey cup" morphology, allowing patients to drink in a chin-tuck posture to naturally close the airway.

2) But the infrastructure for controlling tremor, F1 in early Q1:statusupdate as it is upgraded from a "high-tech surprise" to an "industry standard configuration. This in turn entails the social domestication of stabilisation technology has been completed. The emphasis on "extreme algorithm hunt" will need to be balanced by design considerations that cater for restability the fluid sealing process necessary to maintain stability and F10 (hygienic efficacy

3) while working with a low battery, thereby avoiding failure-induced distrust .

B. The Dignity Drivers: Destigmatization & Stealth Design

Factors in the second quadrant (Q2) (F13, F15, F14) constitute the "Social Subsystem." The high weight of F13 ($W_g = 0.110$) confirms that "maintaining dignity" has surpassed mere functional compensation to become the key to adherence.

1) Destigmatization: Safety has the highest weighting, as might be expected, and F13 (taste aesthetics) is next in line. This finding is in line with Goffman's stigmasation theory [7], that abnormal assistive devices are "stigmata amplifiers" causing the individuals to perform a "spotlight attention". So, the kernel of this dignity-driven strategy is in fact “de-labelling”: rightly a semiotic connection smartphone and disabled identity.

2) Stealth Design Strategy: We propose a "Stealth Design" strategy that appropriates mainstream aesthetic features:

- Color: Abandon "Medical Blue/White" in favor of Morandi colors or home decor tones to achieve visual integration.
- Material: Combine F5 (High Friction) with F13, utilizing skin-like coatings or precision metals to convey the texture of "precision instruments" rather than "rehabilitation toys."

- Form: Referencing the VerStick concept [17], adopt minimalist geometric forms to avoid exposed mechanical structures.

3) Normalization via Modularity: The high ranking of F15 ($W_g = 0.090$) reveals the "Continuity of Life." Thus, rebuilding the "disability-specific tool" into a "Multi-functional Lifestyle Kit," taking advantage of its modular structure to frame as it stages and greatly reducing psychological threshold for use.

C. Collaborative Support: Making Invisible Work Visible

Users of assistive technology also include caregivers. Traditional designs often overlook "Invisible Work" such as maintenance and cleaning.

1) Physical Offloading: F15 (Modularity) consolidates multiple maintenance tasks into one, resolving "tabletop clutter." Simultaneously, the high satisfaction ($SI = 0.73$) of F8 (Battery-free Operation) corroborates the value of "Low Maintenance." Compared to active electronic devices, passive solutions eliminate the burden of charging and firmware updates [14], minimizing intrusion into family routines.

2) Digital Decluttering: Regarding F11 (Tremor Monitoring) in Q4, we propose a firm recommendation for elimination. Although IoT is exalted [12], mere data recording constitutes "Data Labor" [30]. If data cannot be translated into therapeutic decisions, it merely consumes user attention.

D. Design Verification: Conceptual Proposal

To validate the practical applicability of the proposed framework, a conceptual product named "SteadyCompass" was developed, integrating the top-ranked strategies identified in the Strategy Quadrant (Fig. 4).

1) Product Architecture:

- Core Function (Active Stabilization, F1): Unlike passive weighted spoons, SteadyCompass incorporates a miniature high-speed servo motor system within the handle. This system generates reverse-phase motion to counteract physiological tremors in real-time, fulfilling the fundamental "Hygiene" requirement ($W_g = 0.149$).
- Smart Integration (Tremor Monitoring, F11): Embedded IMU sensors continuously log tremor frequency and amplitude during meals. This data is visualized in a companion app, transforming the device from a mere tool into a health management terminal, addressing the "Must-be" intelligence need ($W_g = 0.095$).
- Visual Semantics (Discreet Aesthetics, F13): Adhering to the "Dignity Driver" principle, the device abandons the traditional "medical device" look (e.g., bulky plastic, bright colors). Instead, it utilizes a medical-grade stainless steel finish and a slim ergonomic profile that mimics standard tableware, ensuring the technology remains "invisible" to reduce social stigma.

2) Usage Scenario (Storyboard Description):

- Phase 1 (Pre-meal): The user removes the device from a portable charging case. Its appearance is indistinguishable from regular cutlery, allowing the user to dine in public without attracting attention.
- Phase 2 (Dining): Upon detecting hand contact, the stabilization algorithm activates automatically. The spoon head remains level despite hand tremors, preventing food spillage and restoring user confidence.
- Phase 3 (Post-meal): After dining, the device syncs the meal duration and tremor data to the cloud. The user's neurologist accesses this report to adjust medication dosages remotely, closing the loop of collaborative care.

E. Validation & Limitations

The hybrid model proposed in this study demonstrates high internal validity through "Methodological Triangulation": Kano and AHP dually validated the "Value Misalignment" of F11 and the "Dignity Driver" status of F13. However, limitations remain:

- Sample Bias: Subjects were primarily H&Y stage 1 – 3 patients. For advanced patients, the weight of dignity might yield to survival maintenance.
- Digital Divide: The digital literacy of elderly subjects limited the acceptance of IoT, though this conclusion may change with future generations.
- 3)Cultural Context: The model has not yet included metrics specific to Asian "Chopstick Ergonomics," warranting future localized research [30],[31].

V. CONCLUSION

Addressing the persistent "high-tech investment, high abandonment" paradox in the field of Parkinson's feeding aids, this study endeavors to reconstruct the value assessment system of design from the decision-making source. This study achieved the following main conclusions and prospects through construction and validation of hybrid PRISMA-Kano-AHP Multi-Criteria Decision-Making model.

A. Research Summary & Core Contributions

The primary academic and practical contributions of this study are manifested in three dimensions:

1) Methodological Innovation: Thus, this study can be considered the combination of both breadth and depth from classical Systematic Review (PRISMA), a deep psychological insight provided by Kano Model followed by an AHP-based decision-making understanding. This MCDM framework effectively overcomes the key challenge of quantitative workflows having limited capability to incorporate qualitative needs (e.g., dignity) and hence moves from an "Experience-Driven" paradigm toward a "Data-Driven" one.

2) V alue Revaluation: The results subvert traditional "Functionalism." The high weight for F13 Discreet Aesthetics ($W_g = 0.110$), data supporting in practice the notion that "Destigmatization" and its logical correlate, namely — i.e., low on math="Reduction of Invisible Work", "Humanistic Discipline". For example, F11 (IoT Monitoring) has been pushed towards Q4 — a clear rebuke of the "Over-medicalization" trend on the supply side and an articulation in support for "Technological Temperance."

3) Strategic Guidelines: This paper provides a hierarchical strategy set with three levels by the way of safety-dignity-collaboration logic foundation on decision matrix：

- Q1 Survival Cornerstone: Establish the swallowing safety red line centered on F3 (Fluid Flow Control).
- Q2 Growth Engine: Identify "Stealth Design" and "De-labeling" as the core breakthroughs for experience.
- Q4 Liability Pruning: Eliminate invalid data functions to alleviate the cognitive load on patients。

B. Future Directions

Based on the limitations of the study, future work will focus on:

1) Non-contact Sensing: For example, contact tracing (F11) was removed due to an increased burden while in the future research needs to be done around Computer Vision technologies powered by AI. This also solves the issue in Q4, where we were not preserving any clinical data despite delivering "Zero-disturbance" by recording tremors with environmental cameras.

2) Cultural Adaptation: To address the Asian context, future research will also introduce "Chopsticks Ergonomics" balancing upon fixture and virtuosity in high-degree-of-freedom manipulations for advances to a fully global universal integration of our model.

C. Final Remarks

It is not just loss of motor skills, as in strip away to the core: empty hole parkinson's disease.

The ideal feeding device the mechanical corrective glove should to be warm, seeking not only ‘Prosthetics for the Body’, replying just a pretty cold quenching tremor but also announced as one’s presence and similarly contravenes this violation [32], [33].

REFERENCES

[1] Dorsey, E. R., Elbaz, A., Nichols, E., Abbasi, N., Abd-Allah, F., Abdelalim, A., ... & Murray, C. J. (2018). Global, regional, and national burden of Parkinson's disease, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. The Lancet Neurology, 17(11), 939-953.

[2] Dirkx, M. F., Zach, H., Bloem, B. R., Hallett, M., & Helmich, R. C. (2018). The nature of postural tremor in Parkinson disease. Neurology, 90(13), e1095-e1103.

[3] Pathak, A., Redmond, J. A., Allen, M., & Chou, K. L. (2014). A noninvasive handheld assistive device to accommodate essential tremor: a pilot study. Movement Disorders, 29(6), 838-842.

[4] Phillips, B., & Zhao, H. (1993). Predictors of assistive technology abandonment. Assistive technology, 5(1), 36-45.

[5] McCreadie, C., & Tinker, A. (2005). The acceptability of assistive technology to older people. Ageing & Society, 25(1), 91-110.

[6] Oro, B. (2025). Perspective Chapter: Designing for Dignity–The Role of Esthetic Empathy in Assistive Technologies.

[7] Goffman, E. (2009). Stigma: Notes on the management of spoiled identity. Simon and schuster.

[8] Pullin, G., & Higginbotham, J. (2010). Design meets disability.

[9] Star, S. L., & Strauss, A. (1999). Layers of silence, arenas of voice: The ecology of visible and invisible work. Computer supported cooperative work (CSCW), 8(1), 9-30.

[10] Mortenson, W. B., Demers, L., Fuhrer, M. J., Jutai, J. W., Lenker, J., & DeRuyter, F. (2013). Effects of an assistive technology intervention on older adults with disabilities and their informal caregivers: an exploratory randomized controlled trial. American Journal of Physical Medicine & Rehabilitation, 92(4), 297-306.

[11] Van Den Heuvel, L., Dorsey, R. R., Prainsack, B., Post, B., Stiggelbout, A. M., Meinders, M. J., & Bloem, B. R. (2020). Quadruple decision making for Parkinson’s disease patients: combining expert opinion, patient preferences, scientific evidence, and big data approaches to reach precision medicine. Journal of Parkinson’s Disease, 10(1), 223-231.

[12] HADDAD, N., & ESTEPHAN, E. (2025, October). SteadySpoon: An IoT-Enabled Stabilizing and Diagnostic Assistive Device for Parkinson's Tremors. In 2025 Eighth International Conference on Advances in Biomedical Engineering (ICABME) (pp. 1-5). IEEE.

[13] Fromme, N. P., Camenzind, M., Riener, R., & Rossi, R. M. (2019). Need for mechanically and ergonomically enhanced tremor-suppression orthoses for the upper limb: a systematic review. Journal of neuroengineering and rehabilitation, 16(1), 93.

[14] Buki, E., Katz, R., Zacksenhouse, M., & Schlesinger, I. (2018). Vib-bracelet: a passive absorber for attenuating forearm tremor. Medical & biological engineering & computing, 56(5), 923-930.

[15] Bhidayasiri, R., Chaisongkram, A., Anan, C., & Phuenpathom, W. (2024). User-centred design, validation and clinical testing of an anti-choking mug for people with Parkinson’s disease. Scientific reports, 14(1), 14165.

[16] Fromme, N. P., Camenzind, M., Riener, R., & Rossi, R. M. (2019). Need for mechanically and ergonomically enhanced tremor-suppression orthoses for the upper limb: a systematic review. Journal of neuroengineering and rehabilitation, 16(1), 93.

[17] Wong, C., & Chan, K. L. (2000, July). Development of a portable multi-functional patient monitor. In Proceedings of the 22nd Annual International Conference of the IEEE Engineering in Medicine and Biology Society (Cat. No. 00CH37143) (Vol. 4, pp. 2611-2614). IEEE.

[18] Ma, H. I., Hwang, W. J., Tsai, P. L., & Hsu, Y. W. (2009). The effect of eating utensil weight on functional arm movement in people with Parkinson’s disease: a controlled clinical trial. Clinical rehabilitation, 23(12), 1086-1092.

[19] Kumar, S., Mehdi, S. M. Z., & Seo, Y. (2024). 1D MXenes: synthesis, properties, and applications. Small, 20(49), 2405576.

[20] McNaney, R., Vines, J., Roggen, D., Balaam, M., Zhang, P., Poliakov, I., & Olivier, P. (2014, April). Exploring the acceptability of google glass as an everyday assistive device for people with parkinson's. In Proceedings of the sigchi conference on human factors in computing systems (pp. 2551-2554).

[21] Lora-Millan, J. S., Delgado-Oleas, G., Benito-León, J., & Rocon, E. (2021). A review on wearable technologies for tremor suppression. Frontiers in neurology, 12, 700600.

[22] Cavalcanti, A., Amaral, M. F., Silva e Dutra, F. C., Santos, A. V., Licursi, L. A., & Silveira, Z. C. (2020). Adaptive eating device: performance and satisfaction of a person with parkinson’s disease. Canadian Journal of Occupational Therapy, 87(3), 211-220.

[23] Norman, D. (2013). The design of everyday things: Revised and expanded edition. Basic books.

[24] Neira-Rodado, D., Ortíz-Barrios, M., De la Hoz-Escorcia, S., Paggetti, C., Noffrini, L., & Fratea, N. (2020). Smart product design process through the implementation of a fuzzy Kano-AHP-DEMATEL-QFD approach. Applied sciences, 10(5), 1792.

[25] Danner, M., Hummel, J. M., Volz, F., Van Manen, J. G., Wiegard, B., Dintsios, C. M., ... & IJzerman, M. J. (2011). Integrating patients' views into health technology assessment: Analytic hierarchy process (AHP) as a method to elicit patient preferences. International journal of technology assessment in health care, 27(4), 369-375.

[26] Karsak*, E. E., & Ahiska, S. S. (2005). Practical common weight multi-criteria decision-making approach with an improved discriminating power for technology selection. International Journal of Production Research, 43(8), 1537-1554.

[27] Saaty, T. L. (2008). Decision making with the analytic hierarchy process. International journal of services sciences, 1(1), 83-98.

[28] Kalf, J. G., De Swart, B. J. M., Bloem, B. R., & Munneke, M. (2012). Prevalence of oropharyngeal dysphagia in Parkinson’s disease: a meta-analysis. Parkinsonism & related disorders, 18(4), 311-315.

[29] Wang, R., Ding, W. Y., Zhou, Z. Y., Li, X. C., & Zhang, Y. F. (2025). Optimizing equipment requirements and configuration rules for elderly home treatment environments: a rough set analysis framework. Frontiers in Medicine, 12, 1700646.

[30] Greenhalgh, T., Wherton, J., Papoutsi, C., Lynch, J., Hughes, G., Hinder, S., ... & Shaw, S. (2017). Beyond adoption: a new framework for theorizing and evaluating nonadoption, abandonment, and challenges to the scale-up, spread, and sustainability of health and care technologies. Journal of medical Internet research, 19(11), e8775.

[31] Vines, J., McNaney, R., Clarke, R., Lindsay, S., McCarthy, J., Howard, S., ... & Wallace, J. (2013). Designing for-and with-vulnerable people. In CHI'13 Extended Abstracts on Human Factors in Computing Systems (pp. 3231-3234).

[32] Kenny, L., Moore, K., O'Riordan, C., Fox, S., Barton, J., Tedesco, S., ... & Timmons, S. (2022). The views and needs of people with Parkinson disease regarding wearable devices for disease monitoring: mixed methods exploration. JMIR Formative Research, 6(1), e27418.

[33] Scherer, M. J. (1996). Outcomes of assistive technology use on quality of life. Disability and rehabilitation, 18(9), 439-448.