

USER-CENTERED DESIGN IN WARDROBES: A SYSTEMATIC REVIEW

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Abstract. The wardrobe, as a fundamental component of domestic space, mediates the daily ritual of clothing selection, storage, and self-presentation, yet its design has historically been driven by manufacturing conventions rather than systematic engagement with user needs. Following PRISMA 2020 guidelines, this systematic review conducted a comprehensive literature search across Scopus and Web of Science. After strict screening based on inclusion and exclusion criteria, 68 high-quality studies were finally included for systematic coding and thematic synthesis. Thematic synthesis yielded seven interconnected themes: user needs and requirements, ergonomic design, cognitive and behavioral dimensions, smart and intelligent wardrobes, customization and modular systems, accessibility and inclusive design, and cultural and aesthetic considerations. Findings reveal that UCD methods can substantially improve wardrobe usability, accessibility, and user satisfaction, yet the literature remains fragmented across disciplinary silos, methodologically constrained by short-duration laboratory studies. Three critical research gaps are identified: the absence of longitudinal field studies, insufficient participant diversity, limited real-world validation of smart wardrobe prototypes, poor integration across thematic domains, and neglect of sustainability as a design dimension. The review concludes by articulating a forward-looking research agenda and practical guidance for designers, manufacturers, and educators seeking to place the user at the center of wardrobe design.

Keywords: *user-centered design, wardrobe, systematic review, smart furniture, inclusive design*

Introduction

The wardrobe occupies a unique and underexamined position in the domestic landscape (Maguire and Fahy, 2022). It is simultaneously a utilitarian storage vessel, a stage for the daily performance of identity, and a mirror of consumption patterns and material culture (Heinze, 2021; Mellander and Petersson McIntyre, 2021). Each morning, billions of individuals engage in a tacit negotiation with their wardrobe and reassessing a ritual so deeply habituated that its design implications have largely escaped sustained scholarly attention. Yet the wardrobe is far from a neutral container. Its dimensions, internal configuration, illumination, materiality, and hardware determine what is visible, what is accessible, what is preserved, and, ultimately, what is worn. Historically, wardrobe design has followed a trajectory of incremental refinement rooted in craft tradition and industrial manufacturing logic (Ma et al., 2024; Fu et al., 2020). The ornate armoires of seventeenth-century France, the fitted closets of mid-century America, and the modular flat-pack systems of contemporary Scandinavia each embody the aesthetic sensibilities and production technologies of their respective eras (Elworthy, 2026; Jones, 2023). What has been conspicuously absent from this evolution is a rigorous, empirically grounded engagement with the end user. Their body dimensions, movement patterns, cognitive strategies, emotional attachments to clothing, and the social meanings they invest in the act of dressing.

The paradigm of User-Centered Design (UCD) offers precisely this corrective (Daggubati, 2024; Abras et al., 2004). Formally defined in ISO 9241-210:2019 as an approach to system development that aims to make systems usable and useful by focusing on users, their needs and requirements, and by applying human factors, ergonomics, and usability knowledge and techniques, UCD operationalizes user engagement through iterative cycles of contextual inquiry, participatory prototyping, and empirical usability evaluation (Bonet-Olivencia et al., 2024; Gharaei et al., 2024). Originally developed within the domain of human-computer interaction, UCD principles have since diffused productively across product design, architectural design, and furniture engineering (Gharaei et al., 2024). Their systematic application to wardrobe systems, however, remains nascent, scattered, and heretofore unsynthesized. Three converging developments make a systematic review of UCD in wardrobe design both timely and necessary (Rana et al., 2024; McBee-Black, 2022). First, the global wardrobe and closet market was valued at approximately USD 68 billion in 2023 and is projected to grow at a compound annual growth rate of 5.8% through 2032, a trajectory driven by accelerating urbanization, shrinking residential footprints, and rising consumer expectations for personalized living environments. Second, the proliferation of Internet of Things technologies has extended into the domestic sphere, yielding a new category of "smart wardrobes". These innovations introduce novel human-machine interaction challenges that demand UCD expertise to ensure they serve genuine user needs rather than technological novelty (Valderrama-Ulloa et al., 2026). Third, profound demographic shifts create an urgent imperative for wardrobe designs that accommodate diverse physical and cognitive capabilities across the lifespan (Yang et al., 2024).

Despite these converging pressures, no systematic review has yet mapped the landscape of UCD research as it pertains specifically to wardrobe systems. Existing reviews address adjacent domains, but the wardrobe, as a distinctive design object with its own ergonomic, cognitive, and cultural specificities, remains unexamined. This gap constitutes both a scholarly oversight and a practical impediment: without a consolidated evidence base, designers and manufacturers lack the empirical foundation to make defensible, user-centered decisions. This review pursues three objectives: (1) to identify, categorize, and critically synthesize peer-reviewed research that applies UCD principles to wardrobe systems; (2) to map the thematic structure of this literature, revealing areas of concentration and neglect; and (3) to articulate a forward-looking research agenda grounded in identified gaps.

Research questions

Four research questions guide the inquiry:

RQ1: What UCD methods have been employed in wardrobe research, and with what frequency and rigor?

RQ2: What user needs, preferences, and pain points have been empirically documented in relation to wardrobe systems?

RQ3: How have smart and intelligent wardrobe technologies been evaluated from a user-centered perspective?

RQ4: What gaps and opportunities exist for advancing user-centered wardrobe design research and practice?

Materials and Methods

Review protocol and search strategy

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2022; Rethlefsen and Page, 2022). A review protocol specifying the search strategy, inclusion and exclusion criteria, data extraction procedures, and synthesis approach was developed prior to commencement and registered to ensure methodological transparency and mitigate the risk of post hoc decision-making. A comprehensive electronic search was executed across databases selected for their complementary disciplinary coverage: Scopus (multidisciplinary, with strong engineering and design holdings) and Web of Science Core Collection (science and social science). The search string combined three concept clusters using Boolean operators. The first cluster captured UCD terminology: "user-centered design," "user centred design," "human-centered design," "human centred design," "UCD," "participatory design," and "co-design." The second cluster targeted the design object: "wardrobe," "closet," "clothing storage," "clothes storage," "armoire," "dressing room," and "walk-in closet." The third cluster specified the evaluative dimension: "design," "usability," "ergonomics," "human factors," "interaction," and "evaluation." The search was executed in January 2025 and restricted to English-language, peer-reviewed journal articles, conference proceedings, and academic book chapters published between January 2000 and December 2024. This twenty-five-year window was chosen to capture the period during which UCD matured as a formalized discipline, digital technologies began to permeate domestic furniture, and inclusive design gained traction as a research priority.

Literature screening process

A total of 1,247 initial literature records were retrieved through database retrieval. After removing duplicate documents, 935 valid records were retained. Preliminary screening based on titles and abstracts eliminated literature focusing solely on general furniture design without wardrobe specificity, purely technical descriptions of smart wardrobe systems without user evaluation, and non-empirical opinion pieces or trade publications, leaving 142 articles for full-text evaluation. The final included literature must meet the following inclusion criteria: (1) The research theme is closely related to the application of user-centered design, human-centered design, participatory design, or co-design methods in the context of wardrobe, closet, or clothing storage systems; (2) The research objects are wardrobe systems including fitted wardrobes, freestanding armoires, walk-in closets, and smart wardrobe prototypes in residential or commercial contexts; (3) The research methods include empirical analysis through qualitative approaches (e.g., contextual inquiry, semi-structured interviews, diary studies), quantitative approaches (e.g., controlled experiments, anthropometric measurement, survey research), or mixed-methods designs; (4) The literature has complete research conclusions, clearly reported participant demographics, and transparent methodological procedures. The exclusion criteria are as follows: (1) Literature focusing on general furniture design, interior decoration, or architectural space planning without involving wardrobe-specific investigation; (2) Pure technical system descriptions of smart wardrobe hardware, firmware, or software without user-facing evaluation and empirical data collection; (3) Research focusing on fashion design, textile science, or clothing consumption behavior at the level of garment design without addressing the storage

system; (4) Literature with incomplete data, unclear research logic, non-peer-reviewed status, or repeated research conclusions. After strict screening, 68 high-quality literatures were finally included for systematic coding and thematic analysis.

Data extraction and quality assessment and technical roadmap of the systematic review

A standardized data extraction form was developed and piloted on five randomly selected studies before full deployment. For each included study, the following data were extracted: bibliographic information (authors, year, publication venue), study design and methodological approach, participant demographics (sample size, age range, geographic location, any reported disability status), UCD methods employed (e.g., contextual inquiry, persona development, co-design workshops, usability testing, heuristic evaluation), wardrobe type (fitted, freestanding, walk-in, smart/technologically augmented), key empirical findings, reported limitations, and funding sources. Data extraction was performed by the first author and independently verified for accuracy and completeness by the second author. Given the substantial methodological heterogeneity of the included studies, a single standardized quality appraisal instrument was considered inappropriate (Jayakumar et al., 2022). Instead, each study was assessed using criteria adapted from the Mixed Methods Appraisal Tool, which accommodates diverse research designs within a common evaluative framework (Tovin and Wormley, 2023; Ryan et al., 2022; Thompson et al., 2022). Studies were rated on the appropriateness of the research design to the stated research questions, the adequacy and transparency of data collection and analysis procedures, the coherence between findings and conclusions, and the extent to which limitations were acknowledged. All 68 included studies met the minimum quality threshold for inclusion; no studies were excluded on quality grounds, though quality ratings informed the weight given to individual findings in the thematic synthesis (*Figure 1*).

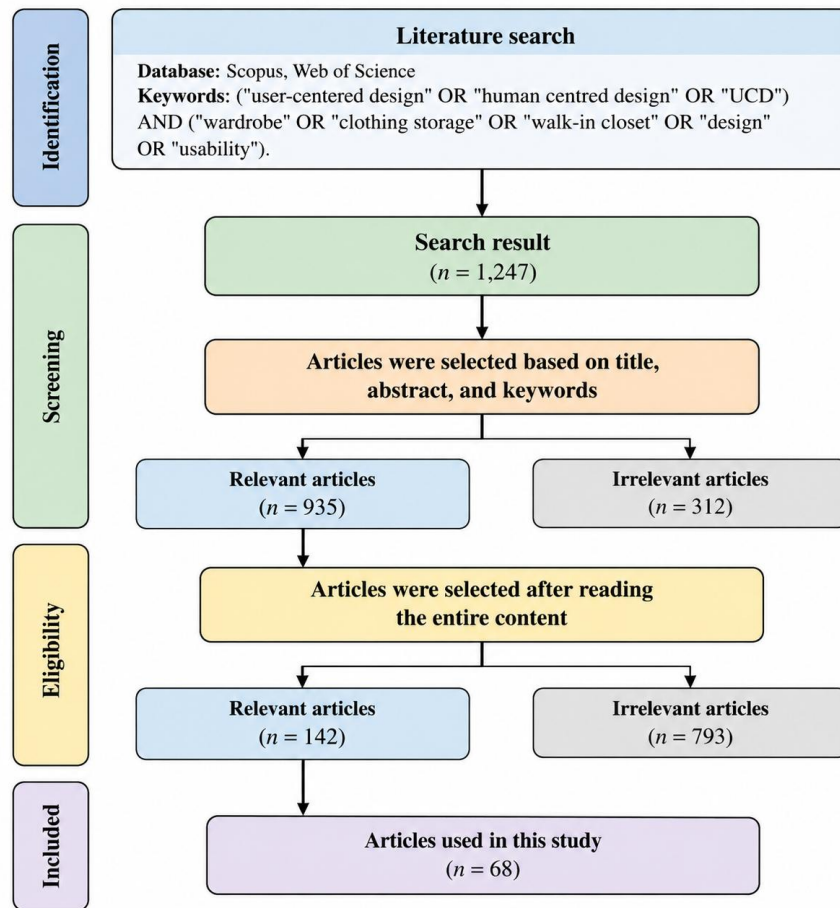


Figure 1. Technical roadmap of the systematic review.

Results and Discussion

The thematic analysis of the 68 included studies yielded seven interconnected themes, each integrating relevant theoretical foundations with the empirical findings of the reviewed literature. *Table 1* presents a quantitative overview of theme distribution across the corpus.

Table 1. Theme distribution across the corpus.

Theme	Number of Studies	Percentage of Corpus
1 User Needs and Requirements	22	32.4%
2 Ergonomic Design	18	26.5%
3 Cognitive and Behavioral Dimensions	9	13.2%
4 Smart and Intelligent Wardrobes	14	20.6%
5 Customization and Modular Systems	8	11.8%
6 Accessibility and Inclusive Design	4	5.9%
7 Cultural and Aesthetic Dimensions	3	4.4%

User needs and requirements in wardrobe design

The largest cluster, 22 studies accounting for 32.4% of the corpus, addresses the elicitation of user needs through semi-structured interviews, contextual inquiry, diary studies, and surveys. Two theoretical frameworks anchor this work. Maslow's hierarchy

has been adapted to distinguish basic functional requirements from higher order psychological needs around identity and self actualization. Norman's three level model of emotional design differentiates sensory appeal from usability and symbolic meaning. Five functional requirements recur consistently across diverse populations. The first is visibility. Wardrobe audit research has documented that garments stored in deep shelves or crowded rails become effectively lost, with participants reporting that 21% of their inventory went unworn over twelve months. The second is accessibility. Observational studies have described the phenomenon of "access friction," whereby digging through piles and overcrowded rails creates a genuine barrier to using owned clothing. The third is capacity, the persistent tension between clothing volume and storage space, intensified by fast fashion. The fourth is organization support. Users develop elaborate categorization systems and experience frustration when configurations fail to accommodate them. The fifth is preservation, concerning protection from dust, light, pests, and deformation. Beyond function, the concept of emotional sustainability has been introduced to describe how chaotic wardrobe environments undermine attachment to clothing (Mellander and Petersson McIntyre, 2021; Heinze, 2021). The wardrobe audit, a facilitated process of reviewing one's clothing holdings, benefits both users through enhanced self knowledge and designers through insight into real world behaviors. A notable methodological concern is the predominance of self report over direct observation; only five studies employed in situ photographic documentation.

Ergonomic design of wardrobe systems

Eighteen studies, 26.5% of the corpus, examine anthropometric and biomechanical dimensions of wardrobe interaction. The central construct is the reach envelope. For a standing adult, the optimal vertical zone extends from approximately 600 mm to 1,400 mm above floor level. Storage beyond these bounds requires postures associated with elevated musculoskeletal risk. Multiple studies confirm that vertical position is the most influential ergonomic parameter. A controlled experiment with 60 Korean adults found that retrieval time increased by 35% and perceived exertion doubled at 2,000 mm compared to the 1,200 mm reference. Items at 400 mm forced squatting or kneeling, rated uncomfortable by 56% of participants over 55. Pull out mechanisms provide clear biomechanical benefits. A within subjects experiment with 40 older adults found that pull out drawers reduced forward reach by 180 mm and lowered L5/S1 spinal loading by 24% compared to fixed shelving. Pull down rails achieved the largest gains, reducing spinal loading by 37%. User preferences aligned strongly: 85% rated pull out mechanisms easier to use, and 92% expressed willingness to pay a premium. Lighting emerged as a significant factor. Measurements across 100 Chinese household wardrobes revealed a median of only 48 lux, far below the recommended 200 to 300 lux. An LED intervention achieving 250 lux reduced retrieval time by 41% and raised satisfaction from 2.8 to 4.3 on a 5-point scale. Comparison of 200 commercial wardrobes with anthropometric databases for five countries revealed systematic mismatches. The mean top shelf height of 2,020 mm exceeded the functional reach of 50th percentile women in all five countries, meaning the top shelf is inaccessible without a step stool for roughly half of female users. Overall, 72% of units placed storage outside ergonomically recommended ranges, revealing a persistent knowledge translation gap.

Cognitive and behavioral dimensions of wardrobe interaction

Nine studies, 13.2% of the corpus, examine cognitive aspects, drawing on distributed cognition theory and the psychology of choice. Distributed cognition proposes that people offload cognitive demands onto their environment through spatial arrangements that cue actions and reduce search costs. The paradox of choice thesis holds that overabundant options produce decision paralysis rather than enhanced freedom, a principle of clear relevance to overfilled wardrobes. Ethnographic studies document the sophisticated spatial strategies users develop: rail order reflecting garment type, color, or frequency; eye level shelves for everyday items; peripheral zones for aspirational pieces; and liminal spaces serving as visual reminders for items in transition. These self-generated strategies represent implicit design that formal UCD can systematize (Daggubati, 2024; Abras et al., 2004). The lost garment phenomenon appears robustly across studies. Participants owned an average of 26 items unworn for over a year, effectively forgotten. Rediscovery during research provoked surprise and guilt. This phenomenon wastes economic value, drives overconsumption as users replace items they cannot find, and undermines emotional connections to clothing (Maguire and Fahy, 2022; Mellander and Petersson McIntyre, 2021; Heinze, 2021). Decision fatigue compounds these challenges, as the morning routine compresses wardrobe interaction into a narrow temporal window under time pressure. The implication is that wardrobes should actively support decision making, not merely provide storage volume.

Smart and intelligent wardrobes

Fourteen studies, 20.6% of the corpus, investigate digital wardrobe technologies, a domain expanding rapidly since 2015. Unlike the ergonomics and user needs literatures, this domain is characterized by a technology driven orientation: prototypes developed first, user evaluation following later. This approach has been critiqued as technological solutionism, and several studies call for rebalancing toward user centered methodologies (Yang et al., 2024; Bonet-Olivencia et al., 2024; Daggubati, 2024; Abras et al., 2004). Digital inventory management is the most researched function. A Korean field trial of an RFID based smart closet across 12 households documented rediscovery of an average 8.3 forgotten garments and reduced duplicate purchasing. However, manual tagging of garments, requiring approximately 15 minutes per wardrobe, emerged as the primary adoption barrier. Outfit recommendation systems using machine learning achieved higher satisfaction than rule based alternatives (4.1/5 vs. 3.6/5), but users expressed concerns about algorithmic transparency and a desire to retain decision making agency. Automated garment care functions have drawn mixed responses. A Japanese field trial found that 34% of participants felt uneasy about delegating care decisions, particularly for sentimental or delicate items. Structural limitations across this literature are notable. The median evaluation period is two weeks, insufficient to distinguish novelty effects from sustained integration. Participants are overwhelmingly young and technically literate, limiting generalizability. Smart wardrobes are evaluated as stand alone objects rather than within the broader domestic technology ecology.

Customization, modularity and mass customization

Eight studies, 11.8% of the corpus, address customization and modularity as strategies for achieving user fit without bespoke costs. This literature is grounded in mass customization theory, with modular systems such as IKEA's PAX range serving as the primary practical realization. A critical finding is the gap between theoretical

flexibility and actual user behavior. A survey of 500 modular wardrobe owners found that 68% retained the default configuration. Three barriers emerged: cognitive uncertainty about optimal layouts, the perceived time cost of reconfiguration, and physical difficulty in adjusting components. The implication is that modularity alone is insufficient without decision support tools and reduced effort designs. Digital configuration tools respond to this gap. A web based anthropometry driven configurator tested in a randomized controlled trial with 120 participants yielded significantly higher satisfaction (4.4/5 vs. 3.7/5) and 2.3 times higher likelihood of deviating from defaults. The tool's key value was providing users with confidence through anthropometric rationale. At the frontier, parametric design for CNC fabrication remains predominantly technical, with empirical studies of user experience remaining rare (Ma et al., 2024; Fu et al., 2020).

Accessibility and inclusive design

Only four studies, 5.9% of the corpus, address accessibility, making this the most underrepresented theme. The theoretical foundations rest on Universal Design's seven principles and the Inclusive Design paradigm, both emphasizing design for the full range of human diversity (Valderrama-Ulloa et al., 2026; Rana et al., 2024; McBee-Black, 2022). One of the most rigorous studies in the corpus was a six month participatory design process with 24 Turkish older adults aged 65 to 88. Key problems included reaching high rails, gripping small handles, reading labels in dim light, and bending to low storage. Co designed solutions included counterweight assisted pull down rails, D shaped handles requiring hook rather than pinch grip, motion sensor LED lighting, and an elevated base plinth. A three month evaluation documented 47% faster task completion, SUS improvement from 42 to 78, and participants reporting more deliberate dressing with less wardrobe avoidance. Wheelchair accessibility research with 15 participants documented barriers including fixed rails at 1,700 to 1,900 mm beyond seated reach, floor level storage requiring hazardous forward lean, hinged doors obstructing approach paths, and insufficient maneuvering clearance. A proposed specification includes sliding doors, electrically adjustable rails, and minimum 1,500 by 1,500 mm clear floor area. Despite Universal Design's maturity as a framework, wardrobes designed from the outset to these principles and evaluated with diverse populations remain strikingly absent.

Cultural and aesthetic dimensions

Three studies, 4.4% of the corpus, address cultural and aesthetic dimensions. This small cluster addresses significant issues given that wardrobe products target a global market while UCD research remains overwhelmingly produced in Western contexts. Cultural analysis draws on material culture studies, which examine how domestic objects embody social meaning (Jones, 2023; Maguire and Fahy, 2022; Mellander and Petersson McIntyre, 2021; Heinze, 2021). The only cross cultural comparison, covering Chinese, Japanese, and British households, revealed systematic differences. British households predominantly hung garments (70 to 80% on rails) while Japanese households predominantly folded, reserving hanging for outerwear. Chinese households favored glass doors offering partial visibility while Japanese and British preferred opaque doors concealing contents. Spatial locations varied, with British wardrobes concentrated in bedrooms while Japanese homes distributed storage across multiple

zones. These patterns reflect deeper cultural logics concerning privacy, display, order, and spatial separation. Aesthetic experience has received minimal empirical attention. The sole study foregrounding this dimension argues for experience driven design of wardrobe hardware, where the tactile and sensory qualities of interaction are constitutive of satisfaction rather than decorative. A wardrobe inviting pleasurable engagement fosters a qualitatively different relationship with clothing than one that frustrates. This perspective awaits rigorous empirical testing.

Conclusion

The wardrobe is more than a container for clothes. It is an interface between the private body and the social world, a cognitive scaffold for the daily practice of self-presentation, and a material repository of identity, memory, and aspiration (Maguire and Fahy, 2022; Mellander and Petersson McIntyre, 2021; Heinze, 2021). For an object of such profound personal and practical significance, the evidence base for its design has been strikingly thin until recently. This systematic review has mapped 68 studies across seven thematic domains, documenting a field in active transition from craft-based intuition toward evidence-based, user-informed practice. The literature demonstrates that systematic engagement with user needs, ergonomic science, and usability evaluation can yield wardrobes that are more accessible, more efficient, more satisfying, and more meaningful than those produced by manufacturing convention alone (Rana et al., 2024; McBee-Black, 2022; Fu et al., 2020). The evidence supports clear, actionable guidance regarding storage zone height, access mechanisms, illumination standards, and the importance of user engagement throughout the design process (Ma et al., 2024; Gharaei et al., 2024; Abras et al., 2004). Yet the review also reveals a field that remains fragmented, methodologically constrained, and demographically narrow. The predominance of short-duration laboratory studies with young, able-bodied participants in high-income contexts limits the generalizability of findings and leaves critical questions unanswered.

The path forward is clear. It requires longitudinal field studies that track user-wardrobe relationships over seasons and years, not hours. It requires deliberate efforts to engage diverse populations whose needs and perspectives have been systematically marginalized in design research (Valderrama-Ulloa et al., 2026; Rana et al., 2024; McBee-Black, 2022). It requires the smart wardrobe field to rebalance from technology-push toward demonstrated user benefit (Yang et al., 2024; Daggubati, 2024; Abras et al., 2004). And it requires researchers, designers, and manufacturers to work across the thematic silos identified here. The tools, methods, and knowledge to place the user at the center of wardrobe design already exist (Bonet-Olivencia et al., 2024; Gharaei et al., 2024; Daggubati, 2024; Abras et al., 2004). What is needed now is the institutional commitment, the scholarly infrastructure, and the professional will to apply them systematically, but actively support the human practices of dressing, expressing, and becoming.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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