

Smart Homes, Real Needs: A Human-Centered Approach to Prioritizing User Requirements for Smart Home Business and Service Models

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Abstract

User adoption of smart home systems remains below projections due to a disconnect between technology-driven developments and user requirements. This research systematically investigates user requirements across seven categories using card sorting methodology with diverse user segments: functionality; value and usefulness; security, privacy and trust; legal regulations and ethics, integration and interoperability, accessibility and user empowerment as well as sustainability. By distinguishing between mandatory “deal-breaker” requirements and optional “value-adding” requirements, this study contributes a multidimensional understanding of factors shaping user acceptance and long-term engagement. Expected findings will inform the refinement of theoretical models (e.g., technology acceptance, privacy calculus, digital ecosystem participation) and provide actionable guidance for practitioners to strategically allocate resources, prioritize development roadmaps, and design trustworthy, empowering smart home services.

Keywords

Smart home, User requirements, Technology adoption, Trustworthy systems, Card sorting

1. Introduction

Smart home systems envision a dynamic living environment that anticipates and responds to the needs of its inhabitants, promising to transform domestic life in fundamental ways. Spanning adaptive energy management, home security, assisted living support, and personalized comfort, these systems are designed to represent not merely a technological upgrade over traditional home appliances but a genuine paradigm shift in how people inhabit and interact with their homes [1,2].

However, mainstream adoption of smart home systems has not met industry projections, largely due to a disconnect between technology-driven offerings and the nuanced requirements of users [3]. Many potential consumers remain hesitant, deterred by concerns surrounding privacy, security, complexity, and insufficient perceived value of smart home solutions [4,5]. The resulting market stagnation is a major concern for users, incumbent smart home companies, and new entrants alike, as smart home technology risks being perceived as either a novel gimmick or a simple commodity add-on, rather than becoming the core of a responsive and intelligent home environment [6,7].

For smart home services to be sustainable and successful, businesses must deliver solutions that reflect what users truly need and value [5,8]. This research is motivated by the need to bridge the gap between technological innovation and user-centric design. By systematically investigating multifaceted user requirements, from functionality to ethics, this work aims to provide a foundation for developing responsible smart home systems that are both commercially viable and empowering for users.

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2. Theoretical Background

2.1. The Unique Nature of the Smart Home Context

Smart home systems differ fundamentally from conventional digital services. Most digital services rely on episodic, user-initiated interactions. Smart home systems, by contrast, operate continuously and autonomously within the private home, a space afforded a heightened expectation of privacy in both moral and legal terms [2,9]. To deliver their promised functionality, smart home devices must continuously monitor the physical environment using embedded sensors, i.e., to track room temperature, light, or movement sensor readings in order to adapt to home inhabitants' needs and preferences [1,10].

This makes persistent data collection not an ancillary feature but a functional prerequisite, which means that smart home systems may introduce privacy risks that fundamentally exceed those of traditional digital services. While individual smart home data points may appear innocuous in isolation, their aggregation across multiple devices enables the inference of deeply personal behavioral profiles [2,9]. These inferences can reveal information that users never wanted to disclose, such as sleep cycles, household occupancy patterns, daily routines, or health indicators, that remain largely inaccessible to service companies in other contexts such as social media or e-commerce [2,11].

2.2. User Requirements for Smart Home Adoption

This unique context gives rise to a rich and multidimensional set of user requirements that extend well beyond the functional capabilities of individual smart home devices [8,12,13]. Still, research consistently indicates that users are primarily motivated to adopt smart home systems when they perceive a clear functional advantage over existing non-smart alternatives, when the technology aligns with their established routines and lifestyle, and when it delivers tangible hedonic or social value [14–16].

At the same time, research shows that potential and actual smart home users often state clear demands around security, privacy, and control over their data. These requirements are not merely considered desirable features but, for many users, preconditions for smart home system adoption altogether [10,13,17]. Compliance with legal and ethical standards, including transparency about data practices and adherence to regulatory frameworks such as the GDPR, further shapes what users expect from smart home companies [13,18,19].

Beyond these foundational concerns, users require seamless interoperability across smart home devices and brands to avoid vendor lock-in and fragmented experiences, as well as accessible and empowering interfaces that accommodate diverse levels of technical literacy [20,21].

Furthermore, sustainability considerations including energy efficiency and responsible resource use are an emerging requirement dimension, particularly among environmentally conscious user segments [22,23].

Nevertheless, despite the growing articulation of these diverse requirements by users in both research and practice, the smart home industry has remained largely technology-driven, focusing on feature development rather than systematically eliciting and prioritizing what users actually want and need [2,6,24]. This disconnect motivates the present study's user-centered approach to requirements elicitation across all seven dimensions.

3. Method

This research adopts a card sorting design to capture and prioritize citizen requirements for smart home services [25,26], following precedents where card sorting effectively captures information needs and transparency preferences in management research or research on complex systems (e.g., [27] or [28]). Card sorting is particularly suitable for user requirements research because it allows participants to organize concepts based on their mental models, revealing natural groupings and priorities that might not emerge through traditional survey methods. Participants from diverse,

heterogeneous user segments will be asked to group and rank a set of cards, each representing a specific user requirement, which allows for the elicitation of user priorities in a structured yet flexible manner. The card sorting process is structured as follows:

- 1) Scope Definition: Based on a comprehensive literature review and our prior qualitative fieldwork, we identified seven core categories of smart home user requirements as presented in Table 1: 1) Functionality, 2) Value & Usefulness, 3) Security, Privacy & Trust, 4) Legal Regulation and Ethics, 5) Integration & Interoperability, 6) Accessibility & User Empowerment and 7) Sustainability.
- 2) Card Creation: For each category, we developed a set of requirement statements as cards, for instance “end-to-end encryption for all data transmission” or “users must have control over how their data is aggregated and profiled”.
- 3) Participant Engagement: Users sort these cards into the predefined categories and rank them by importance. They also discuss potential trade-offs, conflicts, and synergies between requirements, especially in areas where commercial interests and user expectations may diverge (e.g., data monetization vs. privacy).
- 4) Analysis: The results are analyzed quantitatively (ranking, clustering) and qualitatively (thematic analysis of user reasoning).

Table 1

Overview of the Smart Home requirement categories examined in this research

Category	Description
Functionality	Core capabilities including reliability, performance and adaptive intelligence of devices and services
Value and Usefulness	Solutions that deliver tangible benefits with clear problem-solution fit, transparent cost structures, and demonstrable value from data sharing across varied price points
Security, Privacy, and Trust	Robust data protection mechanisms featuring user control options and transparent data practices
Legal Regulations and Ethics	Compliance with regulations, ethical data principles and accountability frameworks
Integration and Interoperability	Seamless cross-device and cross-brand compatibility within open ecosystems that prevent vendor lock-in
Accessibility and User Empowerment	Intuitive interfaces with clear explanations, comprehensive onboarding, and accommodation for diverse user needs (e.g., provision of granular control options if requested)
Sustainability	Energy-efficient systems design considering environmental consciousness, circular economy principles, and responsible resource use

4. Potential Implications for Research and Practice

This study has significant implications for smart home research and practice. By systematically prioritizing end-user needs across functional, ethical, and experiential dimensions, the findings

should contribute to a richer understanding of the various factors shaping user acceptance, adoption, and long-term engagement with smart home systems.

In particular, by potentially distinguishing between mandatory “deal-breaker” requirements without which users will not adopt and optional “value-adding” requirements that serve as differentiators that enhance satisfaction, this research should support the development of new models for better understanding users. The prioritization data and qualitative reasoning surfaced by this study can directly inform the refinement of theoretical models, such as technology acceptance [29] or trust calibration [30], privacy calculus [31], or digital ecosystem participation frameworks [32]. It could also provide a foundation that future research can adapt for comparative studies across user groups, geographic regions, or business models, thus helping to unify research often fragmented by disciplinary and industry silos.

For practitioners, the prioritized requirements offer actionable guidance for smart home companies, software engineers, and ecosystem designers alike. By structuring requirements into clear categories and surfacing both conflicts and synergies, this research aims to support the co-creation of smart home systems that are genuinely empowering, trustworthy, and sustainable. A better understanding of user priorities, and in particular the hierarchy of mandatory versus optional requirements, enables companies to strategically allocate resources, sharpen their development roadmaps, and craft marketing messages that resonate with the core values and expectations of their users.

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Declaration on Generative AI

The authors have not employed any Generative AI tools.

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