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Development of a Solution for Smart Home Management System Selection Based on User Needs

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Abstract

The complexity of smart home technologies and the need for personalized energy efficiency solutions highlight the importance of user-oriented decision-support tools. This study presents a Smart Home Management System (SHMS) selection solution that combines a web-based dashboard, a mobile application, and a relational database. A 54-question structured questionnaire was designed to capture user requirements, and four alternatives—KNX, JUNG Home, LB Management, and eNet Smart Home—were compared using the Simple Additive Weighting (SAW) method. Evaluation criteria included installation complexity, communication technology, integration and control capabilities, and user experience. The system was implemented with Next.js, React Native, and PostgreSQL, ensuring flexibility, scalability, and secure data management. Preliminary evaluation with specialists (system integrators, architects, designers) and students confirmed the coherence of the questionnaire, the adequacy of criteria, and the clarity of recommendations. Results showed that the tool improves user engagement, reduces decision-making uncertainty, and supports the adoption of energy-efficient residential solutions. The study's main limitation is the small test sample, which will be expanded in future large-scale validation. Planned improvements include interactive product comparisons, cost estimation, adaptive questionnaire logic, and 3D visualizations. Overall, the system bridges the gap between technical SHMS solutions and user-oriented decision-making, offering practical and academic value.

Keywords: mobile application; decision-making; Simple Additive Weighting (SAW); smart home management system (SHMS); KNX; JUNG Home; LB Management; eNet

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1. Introduction

The building sector in the European Union remains one of the main energy consumers; therefore, in pursuit of climate change mitigation goals, special attention is given to their energy efficiency. According to the Directive 2010/31/EU of the European Parliament and of the Council, from 2020 all new buildings must comply with the nearly Zero Energy Buildings (nZEB) standard [1]. This standard is based on minimal energy consumption and the use of renewable energy sources (RES). Such buildings must produce as much energy from RES as they consume [2]. Smart control systems become a key element in implementing nZEB building requirements, as they allow efficient control of energy flows, optimization of heating-cooling cycles, and integration of RES. The implementation of nZEB standards is unimaginable without integrated automated systems that not only reduce energy consumption but also ensure building self-regulation in real time, depending on user behavior and environmental conditions.

Typically, users have limited knowledge about building management technologies, are unaware of how to use smart home functions, and do not know which building management system to choose. This leads to distrust of such technologies, which may also be amplified by data privacy concerns. Previous studies mainly focus on technical aspects of smart homes [3–6], while much less attention is paid to how users make decisions and what barriers they face when adopting smart systems [7,8]. Thus, although psychological and social factors are important, there is a lack of user-oriented decision support tools that could reduce the uncertainty of choice and make technical solutions more understandable to non-specialist users.

To address this gap, this study develops and evaluates a mobile application that enables the personalization of Smart Home Management System (SHMS) selection based on user priorities. Instead of directly analyzing social or psychological aspects, the proposed tool indirectly mitigates them: by providing a clear, structured questionnaire and automated recommendations, it reduces the need for technical expertise, lowers decision-making uncertainty, and builds user confidence. The application evaluates four different technological platforms and applies the Simple Additive Weighting (SAW) method to generate recommendations that match individual user requirements.

Considering these issues, this study raises the following questions: what are the main needs of users when choosing a smart home control system, how can the multi-criteria SAW method be applied to personalize these needs, which of the analyzed alternatives best meets the established criteria, and how the developed decision support tool contributes to user engagement and reducing decision uncertainty.

The results of this study are valuable both to the academic community analyzing the adaptation of smart systems and to industry representatives developing personalized solutions for energy control in residential and commercial buildings. The remainder of this paper is structured as follows: Section 2 justifies the study and presents the applied methodology; Section 3 introduces the research results, including the design of the proposed decision-making system, the user interface, and the preliminary evaluation outcomes; Section 4 discusses the implications of the findings and highlights potential directions for further development; Section 5 concludes the article by summarizing the main contributions and offering recommendations for future research and applications.

2. Justification of the Study, Methodology, and Mobile Application Development Decisions

The methodological foundation of this study is based on a constructivist approach, which focuses on the systematic creation of knowledge through practical interaction, feedback, and continuous improvement. The study was conducted using an iterative information systems development model, which includes literature analysis, comparison of existing solutions, requirements formulation, prototype development, testing, and evaluation. This sequence allows not only the conceptualization of the research object but also the justification of decision-making and evaluation processes through real user experiences.

This methodological approach ensures that the developed system is adapted to the specific needs of users. Due to its iterative nature, the solution is continuously improved based on practical applicability and user feedback, which enables greater functional suitability and user interaction effectiveness of the solution.

In the evaluation phase, a comparative analysis was applied to compare four SHMS based on technical, functional, and user interaction criteria. To also assess individual user needs, a SAW multi-criteria decision-making method [9] was used. This method allows the evaluation of alternatives based on subjective criterion priorities, thus ensuring a user-oriented decision-making process.

2.1. Literature Analysis

This section presents the methodology of the systematic literature analysis applied in the study. The aim was to select the most recent and relevant scientific sources covering the main thematic research areas: Smart Home Control, Smart Home Management Systems (SHMS), energy efficiency, device integration, security, and Internet of Things (IoT) solutions. These topics were chosen due to their interrelation in forming complex smart home solutions and to provide a contemporary, technology-driven foundation for the research.

The literature search was conducted in international scientific platforms—ScienceDirect, IEEE Xplore, and MDPI—which are widely recognized by the scientific community as high-quality sources of academic publications. To ensure the reliability and scientific relevance of the materials, only peer-reviewed articles were included in the analysis. Patents, citations, and other secondary sources were deliberately excluded to maintain data quality and the academic validity of the study.

The analysis covered the period from 2020 to 2026, capturing the significant increase in publications on smart home technologies as well as the latest scientific findings in this field. The number of publications increased significantly after 2020, reflecting growing research interest in advanced control systems. For instance, in the ScienceDirect database, 61,760 publications with the terms "smart home control system" and "smart house management system" in the title were identified before 2020. Between 2020 and 2025, this number rose to 46,743. Since this study was conducted in 2025, the 2026 figures are preliminary and include only articles that have already been accepted for publication (in press). These values are presented for illustrative purposes to highlight the trend, but they should not be interpreted as final. The annual dynamics of publications are presented in Table 1.

Table 1. Annual dynamics of publications on smart home control and management systems in different scientific platforms (2020–2026).

Platforms	Cumulative to 2020	2021	2022	2023	2024	2025	2026 *
ScienceDirect	61,760	8539	8874	8976	10,385	9969	119
IEEE	2336	248	335	344	333	93	0
MDPI	84	17	19	27	15	1	0

* As the year 2025 has not yet ended, and some articles already accepted for publication in 2026 are included, the 2026 data are preliminary.

This trend indicates that most of the relevant research in this field has been conducted in recent years. Although the study also included earlier periods, the main focus remained on the most recent sources, which best reflect the current technological reality.

Recent studies highlight that smart homes represent a practical outcome of energy-efficiency policies, where automated technologies ensure not only reduced consumption but also adaptive, real-time building management [10,11]. In the literature, smart homes are broadly described as integrated environments where different building systems—ranging from comfort and security to energy management—are centrally coordinated [12].

The advancement of smart home systems is directly related to the development of the IoT, which enables the integration of all major household devices into a unified network via wireless communication. These devices are connected through sensors and actuators that communicate with each other and respond to user behavior [2]. As noted by

[13], IoT allows users to control systems remotely—using mobile applications or computers—thereby increasing control flexibility and efficiency. The direction of smart systems development is closely related to the optimization of energy consumption. The goal of these technologies is to reduce energy usage without compromising comfort by applying principles such as energy use only when needed, maximum utilization of RES, and minimal use of non-renewable resources [14]. Table 2 presents an overview of decision-making directions in smart building design.

Table 2. Decision-Making Directions in Smart Building Design.

Topic	References
Practical Applications in Smart Building Design	
Energy Efficiency and Optimization	One of the primary practical applications of smart building design is the optimization of energy efficiency. Advanced technologies such as artificial intelligence (hereinafter AI), machine learning, IoT play a pivotal role in achieving this goal. For instance, AI-driven algorithms can analyze real-time data from building management systems (hereinafter BMS) to predict and optimize energy consumption patterns [15,16]. Similarly, IoT enabled sensors and actuators can monitor and control heating, ventilation, and air conditioning (hereinafter HVAC) systems, lighting, and other energy-intensive components, ensuring that energy usage is minimized without compromising occupant comfort [17,18].
Integration of IoT and BIM	The integration of IoT and Building Information Modelling (hereinafter BIM) is another practical application in smart building design. BIM provides a digital representation of the building, enabling architects and engineers to simulate and analyze various design scenarios. When combined with IoT, BIM can facilitate real-time monitoring and control of building operations, leading to improved energy efficiency and operational efficiency [19,20]. This integration also supports the creation of digital twins, which are digital replicas of physical buildings that can be used to test and optimize design decisions before implementation [19,21].
Smart Sensors and Actuators	The deployment of smart sensors and actuators is a key practical application in smart building design. These devices enable the collection of real-time data on various parameters such as temperature, humidity, lighting, and occupancy. This data can be used to make informed decisions about energy control, leading to significant reductions in energy consumption [17,18]. For example, smart sensors can detect occupancy patterns and adjust lighting and HVAC settings accordingly, ensuring that energy is used only when and where it is needed [17,22].
Renewable Energy Integration	The integration of renewable energy sources into smart building design is another practical application. Building-integrated photovoltaics (BIPV) and solar energy harvesting are being increasingly adopted to reduce reliance on non-renewable energy sources. AI-driven decision-making frameworks can optimize the design and placement of these systems, ensuring maximum energy generation and self-sufficiency [21,23].
Theoretical Frameworks in Smart Building Design	
AI-Driven Decision-Making	AI-driven decision-making is a cornerstone of smart building design. AI algorithms can analyze vast amounts of data from various sources, including IoT sensors, weather forecasts, and occupant behavior, to make optimal decisions about energy management. These decisions can be made at various stages of the building lifecycle, including design, construction, operation, and maintenance [16,24]. For example, AI can be used to optimize building orientation, envelope design, and HVAC systems during the design phase, leading to significant energy savings [25,26].
Emerging Trends in Smart Building Design	
Green Building and Sustainability	Green building and sustainability are emerging trends that are driving innovation in smart building design. Green building certifications such as LEED and BREEAM encourage the adoption of sustainable practices, including energy efficiency, water conservation, and waste reduction. Smart building technologies can support these goals by optimizing resource usage and reducing environmental impact [21].
Human-Centric Design	Human-centric design is an emerging trend that prioritizes occupant comfort and well-being in smart building design. Smart building technologies can be used to create personalized environments that adapt to the needs and preferences of occupants. For example, smart lighting and HVAC systems can adjust settings based on occupant behavior, leading to improved comfort and productivity [17,27].

The literature identifies four main smart energy management strategies:

- Economically oriented, aiming to reduce costs by utilizing lower tariff periods or RES energy [28,29];

- Ecological, aiming to reduce greenhouse gas emissions and dependence on fossil fuels [30,31];
- Comfort strategy, focused on individual user needs [32,33];
- Load management strategy, which balances grid load and allows the system to operate autonomously [29,34,35].

In summary, SHMS plays a significant role in optimizing energy consumption; however, existing literature mostly focuses on technological aspects, paying less attention to the personalization of decision-making at the user level. This gap justifies the need for research focused on user needs analysis and the search for personalized solutions.

The reviewed studies confirm that advanced technologies such as AI, IoT, BIM integration, and renewable energy solutions are essential for the development of smart and energy-efficient buildings. However, most of these contributions emphasize the technical optimization of systems and pay less attention to how end users make choices when adopting such technologies. The complexity of available solutions, the diversity of communication protocols, and differences in integration capabilities often create uncertainty for users who lack specialized knowledge. This highlights the importance of decision-support tools that can translate complex technical characteristics into user-oriented recommendations. Therefore, the insights from the literature not only guided the selection of SHMS evaluation criteria but also justified the need for a structured questionnaire that directly links technological features with user priorities, thus bridging the gap between technical innovation and practical adoption.

Taking these trends into account, the study further compares four JUNG SHMS solutions in practice.

2.2. Analysis of Existing Solutions

In this study, four building management system product lines from a single manufacturer—JUNG—were selected. These four systems were chosen because they represent different levels of integration and complexity—from simple wireless user-friendly solutions to advanced open standard platforms that allow for assessment of user needs in various technological maturity scenarios. These systems differ in their functionalities and capabilities, thereby addressing diverse user needs: from basic and commonly used functions (the simplest system) to more advanced solutions that integrate building engineering systems and optimize energy consumption (the most complex system). It should be noted that JUNG solutions are not unique; systems based on the same principles are also offered by other well-known manufacturers, such as Gira, ABB, Merten, Hager, and others.

The aim of this article was not to compare different building management system standards. Rather, the main objective was to develop a product tool that assists end users in selecting the most suitable building management system, taking into account their individual needs.

For the study, four SHMS of varying architectural complexity and functional capabilities were selected—Jung Home, Jung KNX, LB Management, and eNet Smart Home. These platforms are widely used in the European market and represent different levels of solution integration—from local control to advanced IoT-based systems. Such selection provides a basis for a representative evaluation, allowing the analysis of the decision-making process in the context of different user needs.

The systems were evaluated based on four essential criteria: energy efficiency, user comfort, integration capabilities, and overall system security. The study also considered the applicability of the solutions in the residential sector and the technical readiness of the end user, aiming to ensure accessibility of the solution to a wider range of users.

Jung Home. Albrecht Jung GmbH & Co. KG, located in Schalksmühle, Germany,created the contemporary smart home system known as Jung Home, which is intended for easy, scalable, and adaptable smart building control, particularly for residences, apartments, and small business spaces [36]. Lighting, HVAC, and shutter automation are all possible with Jung Home Systems. In addition to energy control, this system integrates security and alarms. Voice and/or remote control are available for this system with KNX IP [37] and Alexa, Google Assistant, and Apple HomeKit. The primary feature, applicability, should be considered when comparing these four BMS. Jung Home is considered particularly suitable for high-end residential applications within KNX-based environments. The KNX standard is best suited for big BMS tasks that require flexibility and scalability. For commercial buildings with a lot of HVAC systems, LB Management is appropriate. An affordable cloud-based household option is eNet Smart Home.

Jung KNX. JUNG KNX is widely used in smart building automation and is based on an internationally recognized decentralized bus communication model. Such systems provide interoperability across a wide range of operational and technical services, including lighting, electrical outlets, push buttons, environmental sensors, blinds, HVAC systems, and alarm control [38]. They enable communication between up to 65,536 devices through a 16-bit addressing scheme. Although these systems are effective for low-data-rate signaling and device control, they typically require a dedicated wiring infrastructure, which increases installation costs and complexity. As KNX-compatible, JUNG systems support three topologies—line, tree, and star—and can operate across several transmission media, including KNX-IP (Ethernet), KNX-RF (radio frequency), KNX-PL (power line communication), and KNX-TP (twisted pair cabling) [39]. In addition to these core features, JUNG KNX provides flexibility in system architecture and ensures long-term interoperability due to the open international standard, allowing seamless integration with a broad ecosystem of devices and services, and supporting scalable and reliable building automation solutions [40].

LB Management. The German company JUNG designed the intelligent lighting and load management technology known as LB Management (Load Balance Management). Its goal is to provide automated, easy, and energy-efficient solutions for both residential and commercial buildings [41]. Some benefits of the LB Management System include its compatibility with KNX, its ease of electrical installation, its capacity to automate a single location or the entire compartment, and its reduced cost when compared to a complete KNX bus. Furthermore, the system is not reliant on Wi-Fi, the Internet, or the cloud. Nevertheless, LBMS lacks central control, a voice assistant, and the ability to display logical scenarios without KNX. The system's inability to connect many appliances is its primary drawback [42]. European countries are the main users of the LBMS, particularly in cases where basic local automation of blinds and lighting is required in homes without the need to create a comprehensive bus-based "smart home" system like KNX [43].

eNet Smart Home. eNet SMART HOME is a wireless smart home automation system developed in collaboration between the German companies Gira and JUNG. The system architecture is based on decentralized control and two-way radio communication, which allows the integration of various building components without the need to modify the electrical installation. This technology is becoming especially relevant in renovated homes, where wiring is limited [44]. Unlike traditional systems, eNet SMART HOME allows the user to control lighting, blinds, heating and scenario-based automation solutions via a mobile application. Such user interface solutions, focused on simplicity and adaptability, increase the acceptability of smart systems among a wide segment of consumers [45].

A summary of the comparative characteristics of SHMS is presented in Table 3.

Table 3. Summary of comparative characteristics of SHMS.

SHMS	Jung Home	Jung KNX	LB Management	eNet Smart Home
Type	Smart home system, conventional 230 V installation	Open BMS standard (wired/wireless)	HVAC-focused BMS	Cloud-based smart home
Protocol	Bluetooth® Mesh	KNX (ISO/IEC 14543)	Proprietary (BACnet, Modbus)	IP-based (Wi-Fi, Ethernet)
Building types	Residential homes and offices	Any building size with a global BMS standard	Large building with commercial HVAC	Residential and small commercial
Main features	Lighting, HVAC, security, premium design switches, and KNX integration	Interoperable devices, secure and reliable	Energy optimization, HVAC-centric, BACnet support	Cloud control, App-based automation, Easy DIY setup
Integration	Works with all KNX devices	Compatible with 500+ KNX brands	BACnet, Modbus, KNX gateways	Limited (mostly eNet devices)
Energy Control	Advanced (KNX energy monitoring)	Excellent (open standard)	Best for HVAC efficiency	Basic energy tracking
Security	High	Very high (encrypted)	High (industrial grade)	Medium (cloud-dependent)
Cost	Premium (high-end)	Mid to high (depends on devices)	High (commercial focus)	Affordable (consumer-grade)

2.3. SHMS Selection Questionnaire

Based on the results of the literature analysis and expert recommendations, a structured questionnaire was developed to identify and assess user needs related to the selection of smart home management solutions. The questionnaire was created using scientific sources that emphasize the importance of personalized solution delivery in smart home architecture [46]. Research shows that analyzing user needs is a key prerequisite for the successful implementation of a smart home system; therefore, the questionnaire becomes an important tool for forming the user profile [47,48].

The questionnaire design was informed by literature and expert recommendations, ensuring that it systematically covers both energy-intensive systems (lighting, HVAC, ventilation) and comfort/safety features (security, multimedia, IoT integration). This structure allows a balanced assessment of user needs across the main functional domains of smart home management.

Energy-intensive systems include:

Lighting. Lighting is controlled individually or according to pre-programmed scenarios, maintaining the desired illumination in different rooms of the smart home.

Microclimate. Ventilation, heating, air conditioning, and blinds systems are managed in an integrated manner, thus creating an optimal indoor microclimate.

Temperature. An optimal temperature is maintained in the premises; each room's temperature is regulated separately according to needs, saving energy by heating only when the rooms are occupied.

Blinds. Desired functions can be set based on the time of day, seasons, or selected control mode. For example, blinds can respond to the sun's position relative to the building, outdoor weather conditions, indoor lighting, or temperature.

Security system. Building security is ensured by surveillance and safety systems, which can be integrated into the overall building management system. The security system allows for simulating human presence in the premises, monitoring the building and its surroundings via a smart device.

Multimedia equipment. Comfort is ensured by integrating multimedia systems (audio equipment, televisions, home theater systems) and other household appliances into the building management system, as well as by the ability to control devices via voice commands or smart devices.

When developing the questionnaire for the home management system selection application, a clear and logical structure was followed, based on a hierarchical classification of systems and functional compatibility. Priority is given to essential functions and optimal energy usage. The prepared questionnaire consists of 54 questions covering the main engineering systems of the building—from automation scenarios, lighting, and climate control to security systems, energy source management, and device integration. The structural analysis of the questionnaire is presented in Table 4.

Table 4. Structural Analysis of the Questionnaire.

Question Group	Number of Questions	Main Components
Information about the Object	3	Building type (House/Apartment); Object area; Renovated/Newly built
Main Functions	37	Lighting (12 questions: manual control; automatic control; timers; astronomic control; grouping; light flow regulation [supply voltage, PWM, 0–10 V, DALI]; color change [RGB]; color temperature adjustment); Blinds/Curtains/Shades (5 questions: raising/lowering, slat control, curtain/roller/shade/skylight control); Heating and Air Conditioning (10 questions: radiator heating, underfloor heating, heat pump control, heating/cooling modes, temperature regulation [on/off, proportional, zoning, timer, extra sensor, forecast]); Ventilation (8 questions: on/off, timer, air volume, damper, CO_2 sensor, humidity sensor, heat recovery integration); 1 question: scenario creation; 1 question: weather station integration
Multimedia Integration	1	Multimedia integration into the control system
Management	4	Control via smartphone/tablet; remote control via radio; Google Assistant/Alexa integration; control via browser/computer
Security	5	Video surveillance; Alarm system (motion, door, window sensors; water, smoke, fire sensors); Access control (locks, readers, intercom system)
Additional Features	3	Water control; Energy consumption monitoring; Internet of Things
User Management	1	User accounts and passwords

All questions are divided into seven groups, with each question group reflecting the key components of smart systems most frequently identified as determining user satisfaction and system functionality [49,50]. Studies also show that identifying the connection between system functionality and the user's context allows for anticipating potential needs in advance and ensuring system flexibility [51,52]. In this study, the questionnaire not only served as an inventory of user requirements but also played a methodological role—it systematically linked user needs with the decision-making algorithm, thus forming the basis for generating personalized recommendations.

The questionnaire responses are used for decision personalization and the logic behind recommendation generation. In this way, the survey data serves as input for the mobile application, enabling the formation of a smart home system proposal tailored to the user's needs. According to [53], such a decision model, focused on user needs analysis, increases both the effectiveness of technology application and its acceptance among users. Furthermore, the literature confirms that classifying user needs through a questionnaire can be effectively applied in recommendation systems, especially when based on contextual and semantic information [5].

In addition, the questionnaire includes several different SHMS available on the market (Jung Home, Jung KNX, LB Management, eNet Smart Home) to evaluate their suitability based on the type of property and user priorities. The evaluation of systems applies the principle of a higher-level system—meaning that if a system is more advanced and has more complex features, it is assumed that it also supports all lower-level management system functions. This ensures indirect compatibility, where a more advanced system encompasses the capabilities of simpler systems, allowing for efficient presentation of functional coverage without redundant duplication of information.

Finally, after the desired functions are entered, the application automatically evaluates which of the systems best meets the user's requirements. The evaluation is based on functional compatibility rather than solely on brand or financial criteria, making the decision more objective and better aligned with the user's actual needs. This approach enables the user to quickly and clearly understand which system is most suitable for their home, even if they lack appropriate technical knowledge.

This comparative analysis allows for the integration of both technical characteristics and subjective user needs into the final decision. The applied methodology employs a decision tree algorithm, which is widely recognized in research as being well-suited for classification tasks. Furthermore, decision trees provide straightforward and transparent result interpretation, ensuring that the decision regarding the selection of a home management system is well-founded, understandable, and effectively adaptable to each user's individual needs.

3. Results

3.1. System Design and Technological Justification

This section presents an integrated decision-making system designed for generating personalized SHMS selection recommendations. The solution includes three essential components: a browser-based administration dashboard, a mobile application for end users, and a relational database that ensures information storage and accessibility. The interaction of SHMS Selection System Components is presented in Figure 1.

The administration dashboard allows system administrators to manage user accounts, configure questionnaires, control product packages, and analyze collected statistics. The mobile application for users provides a convenient interface for filling out questionnaires, receiving personalized recommendations, viewing summaries of product technical specifications, reviewing previous responses, and accessing partner contact information.

The system architecture is based on a Representational State Transfer Application Programming Interface (hereinafter REST API), developed using the Next.js v15 platform. The API serves as an intermediary for data exchange between user interfaces and the data storage layer. This solution enables flexibility in deployment environments—both on local servers and in cloud infrastructure—by automatically adapting the configuration to the execution environment.

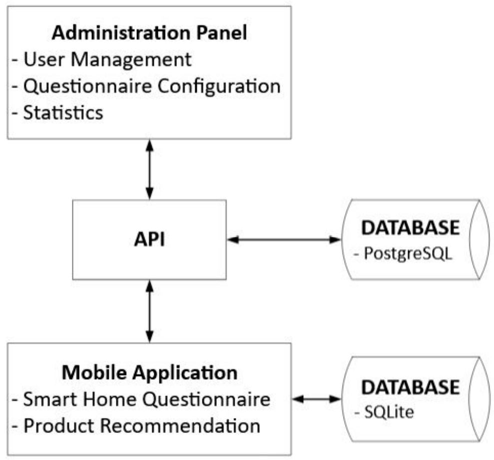

Figure 1. Interaction Diagram of SHMS Selection System Components.

From a technological perspective, the system is implemented using tools from the JavaScript ecosystem compliant with ECMAScript 2024 (ES15): the user interface components are developed with Next.js v15 and Tailwind CSS v4.0, while the mobile application is built on React Native v0.76. For data access and management on the server side, a PostgreSQL v17 database is used. In the API layer, Next.js API routes are implemented and organized by functional areas.

At the functionality level, the system includes two user groups—administrators and end users. The administration dashboard provides the following capabilities: registration and management of administrator-level accounts (limited to the dashboard), questionnaire structure configuration, creation of answer options, assignment of product packages, and review of data analysis. The mobile application for the end user presents a dynamically generated questionnaire, which forms the basis for personalized product recommendations. The recommendations are based on the match between the user's responses and the products available in the system, evaluating their mutual compatibility. The user is also provided with a recommendation match indicator—a percentage score showing how well the proposed product or package aligns with the respondent's answers. This enables the user not only to see the recommended solution but also to assess its relevance based on their individually expressed needs. Additionally, users can access their questionnaire history and contact information for consultants.

A two-tier database architecture is used for system data management, adapted to the operational specifics of different components. On the server side, a PostgreSQL relational database is used, known for its high performance, data integrity assurance, and advanced transaction management capabilities. PostgreSQL efficiently processes complex queries, supports a normalized data model, and ensures secure data consistency when multiple users interact with the system simultaneously. The overall data model is based on several core entities, including users, questions, answers, questionnaires, answer categories, product packages, comments, and invitation links. The tables are interlinked using foreign keys, ensuring a consistent structure and enabling efficient analysis and recommendation generation.

The mobile application includes a local database based on SQLite technology. It operates within the device's internal memory and is used for intermediate data storage and offline functionality. SQLite allows the user to access previously completed questionnaires, received recommendations, and contact information even without a network connection. This type of architecture ensures data integrity on the central server, while also providing the mobile applications with the necessary flexibility, fast access, and partial autonomy.

In the administration dashboard, centrally edited questionnaires, product descriptions, and recommendation logic can be transmitted in real time to both the server side (PostgreSQL) and the mobile application (SQLite) via the API interface. The synchronization process is triggered automatically when the device regains network connectivity or is executed periodically according to a predefined schedule. This data architecture solution ensures smooth operation even under unreliable or limited connectivity conditions and provides the basis for continuous content updates and dynamic data management. It enables rapid system adaptation to new products, market changes, or user needs. Additionally, the automated collection and analysis of responses allow for systematic monitoring of user behavior, identification of the most popular selection combinations, and optimization of the recommendation model based on actual usage data. In this way, the system becomes not only a decision-making tool but also a data-driven analytical platform that supports the improvement of smart home offerings based on real user engagement.

Several measures have been implemented to ensure security: authentication uses the JSON Web Token (hereinafter JWT) mechanism, allowing user identity verification via the Authorization: Bearer header. Access control is implemented using a role-based access control (hereinafter RBAC), which restricts access to system resources based on the user's assigned type. To ensure data confidentiality, HTTP headers are used to prevent result caching, and a maximum waiting time of 30 s is set for requests, adapting to mobile network conditions. In addition, security measures have been applied to reduce the risk of access token leakage.

Furthermore, it is essential to address issues related to data privacy and security, particularly in the context of the General Data Protection Regulation (GDPR). The system does not collect or process personally identifiable information; all user preference data is stored locally on the device and is never shared with third parties. The collected information is utilized solely for the purpose of generating personalized recommendations, and no statistical records are accumulated. This design approach adheres to the GDPR principles of data minimization and privacy by design, ensuring maximum protection of user data and significantly reducing the risk of potential data breaches.

3.2. System User Interface and User Manual

The developed solution includes two complementary interfaces: a web-based administration dashboard for system integrators and consultants, and a mobile application for end users. Together, these components ensure that both professionals and non-technical users can benefit from the tool in an intuitive and transparent way.

The administration dashboard provides all necessary functionalities to configure and maintain the system. It enables administrators to manage invitations and assign roles to consultants and users, define questionnaire categories, and create or edit questions. The question editor supports dependencies, control questions, and collaborative comments, ensuring logical consistency and clarity. The administration dashboard interface is presented in Figure 2.

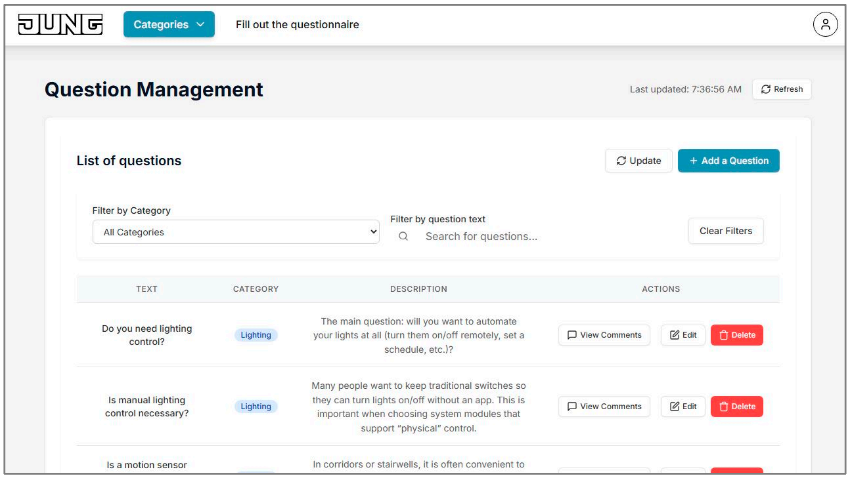

Figure 2. The administration dashboard user interface.

Administrators can also view and organize entire questionnaires and manage product packages, where technical features and recommendations are linked directly to questionnaire answers. The dashboard is intended exclusively for the editing and maintenance of the questionnaire structure. It does not include functionalities related to user data storage or the administrative management of user accounts, roles, or profiles. Such a design choice ensures that the dashboard remains focused on content management without extending into user-level operations.

All end-user data, including completed questionnaires and generated results, is stored solely on users' personal devices. This approach guarantees that sensitive information remains under the direct control of the end user, thereby safeguarding privacy and data security. The architectural decision to decentralize data storage was made deliberately. By avoiding centralized user data management, the system reduces overall complexity while aligning with core principles of data protection and user autonomy. As a result, the application not only supports transparency and security but also enhances user trust in the decision-making process.

The mobile application is designed for end-user interaction and is the core of the decision-making process. The onboarding process begins with a welcome screen and navigation menu, where users can start new questionnaires, review completed ones, or access system information. In some cases, users may also select only specific groups of questions relevant to their needs, such as lighting, multimedia, or security. The mobile application interface view is presented in Figure 3.

Each questionnaire is presented in a step-by-step format, beginning with general object information (e.g., house or apartment) and continuing with functional requirements, such as lighting control. A progress bar and visual indicators keep the user informed about completion status, reducing cognitive load even in longer surveys. Upon completion, the system generates personalized recommendations. Results are shown both as ranked system lists with compatibility percentages and as detailed recommendation cards for each solution. These cards highlight supported and unsupported features, provide system descriptions, and include options to export results as PDF or directly contact vendors.

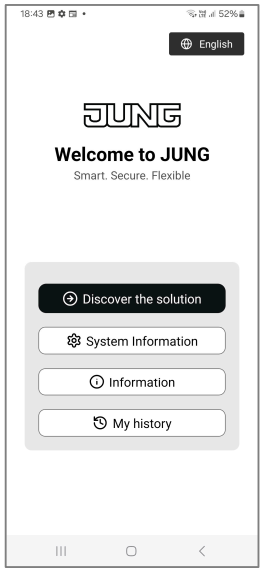

Figure 3. The mobile application user interface.

3.3. Application Evaluation

The evaluation of the developed application was organized as an iterative process, enabling a systematic assessment of its usability, functional validity, and applicability in both professional and educational contexts. In the current stage, only a preliminary evaluation has been completed, serving as a pilot test to gather initial feedback from two distinct user groups: specialists (system integrators, architects, and designers), who assessed the subject-matter accuracy and professional relevance of the tool, and students, who evaluated usability and user experience. The results of this initial stage were positive, confirming the coherence of the questionnaire's structure, the adequacy of the evaluation criteria, and the validity of the generated recommendations.

However, the preliminary assessment represents only the first step of a broader evaluation strategy. To ensure comprehensive and reliable validation, subsequent testing will be carried out in several iterations, each focusing on specific objectives, user groups, and methodological approaches. This structured plan allows gradual refinement of the application, moving from pilot usability validation towards large-scale testing and professional verification. Table 5 summarizes the iterative testing plan designed for the application.

The current findings, corresponding to the first iteration, confirm the application's potential but cannot yet be considered a complete validation. The forthcoming iterations will expand both the scope and the depth of testing, enabling systematic verification of professional applicability and long-term reliability. The implications of these results and the expectations for future testing are discussed in the following Discussion section

Table 5. Iterative Application Testing Plan.

Iteration	Objective	Participants	Methods	Expected Outcome
1. Preliminary Evaluation (Pilot Test)	To obtain initial feedback on questionnaire structure, criteria coverage, and validity of recommendations	Specialists (system integrators, architects, designers); Students	Qualitative feedback, short surveys, and observation	Confirmation of structural coherence, criteria relevance, and initial validation of recommendations
2. Extended Usability and Functionality Testing	To test new features (3D visualizations, adaptive logic, extended explanations) and	Larger group of students and non-specialist users	Task-based usability tests, surveys, interaction analysis	Identification of usability issues, validation of adaptive logic,

	evaluate usability across diverse users	segmented by age and interest		confirmation of comprehensibility
3. Expert Review and Practical Validation	To assess professional applicability and accuracy of recommendations in real project contexts	Industry experts (integrators, architects, designers, engineers)	Scenario-based tasks, expert interviews, comparison with real-world projects	Validation of professional value, proposals for further functional integration (e.g., CAD/BIM tools)
4. Final Validation and Scalability Testing	To ensure stability, scalability, and readiness for deployment	Mixed group of experts, students, and general users	Beta testing, performance monitoring, error tracking, and large-scale surveys	Comprehensive validation of usability, stability, and reliability; confirmation of readiness for practical and educational deployment

4. Discussions

The findings of this study demonstrate a steady growth in publications on smart home management and control systems after 2020, underscoring the increasing relevance of these technologies in the context of energy efficiency and sustainability. The analysis was conducted using reputable international academic platforms that ensure the quality of peer-reviewed sources; nevertheless, the inclusion of a broader range of databases could provide a more comprehensive overview. The variations observed in publication dynamics reflect thematic diversity and differences in publishing practices, while the data for 2026 should be regarded as preliminary.

Notwithstanding these limitations, the study affirms the growing scientific and practical significance of smart home technologies in supporting the transformation of the building sector toward sustainability objectives. Future research directions could include the integration of a wider range of databases, the application of bibliometric approaches, and a more detailed thematic differentiation of publications, with the aim of providing a deeper understanding of the field’s evolution and its implications for systemic innovation.

In addition to the literature trends, the empirical testing of the proposed selection methodology provided practical insights into the decision-making process for building management systems. The methodology was evaluated both by specialists (system integrators, designers, architects) working with real projects and by students (inexperienced users) preparing independent assignments and final theses in the course “Building Management Systems.” Evaluators confirmed that the questionnaire structure enables informed system selection**.** Unlike manufacturer-specific tools, this application is designed as a universal selection system. The JUNG solutions were used solely for system testing and design development purposes.

Nevertheless, the feedback from testers highlighted the need for additional criteria that may influence the selection process. These include:

- **Installation complexity**. This is one of the most important practical criteria. Systems with lower installation complexity and minimal technical requirements (e.g., eNet SMART HOME, JUNG Home) are more suitable for renovation projects or users without engineering experience. In contrast, more complex platforms (e.g., KNX) require qualified specialists but offer greater control capabilities.
- **Manufacturer reliability.** Experience shows that manufacturers of home automation equipment may discontinue specific product lines, leaving users without technical support or security updates, and in some cases rendering devices inoperable. The study used JUNG systems as test cases due to their established presence in the European market.

- **Device design**. This is related to the building's interior concept—a wide range of devices allows for greater variety in interior design solutions. This criterion is important at the early stage of the project and influences the selection of the equipment manufacturer.
- **Communication technology**. The communication technologies used, such as wireless protocols (Bluetooth, REG-Bus), IP protocols, or standardized KNX networks, have a significant impact on integration with other building systems. Open protocols provide broader interoperability with third-party solutions.
- **Control and integration capabilities**. Control mechanisms such as mobile applications, server integration, and compatibility with external platforms reflect the system's flexibility. These criteria are particularly relevant to project developers seeking scalable and user-tailored solutions.
- **User-friendliness.** An intuitive interface, simple and straightforward programming (the ability for the user to program independently), convenient control, and the availability of mobile applications, while not decisive at the technical level, are important to end users and can influence both the decision-making process and the choice of the management system.

The results show that, to effectively select a smart home system, the selection criteria need to be categorized. This approach allows the user to quickly and clearly understand which system is most suitable for their home, even if they do not have the necessary technical knowledge.

From a theoretical perspective, the study contributes to the literature on user-oriented decision-making by demonstrating how a classical multi-criteria evaluation method (SAW) can be successfully adapted to capture individual user requirements in the context of smart home management. While most previous studies emphasized technical optimization of building automation, this research shows how structured questionnaires can serve as an effective bridge between complex technical parameters and subjective user priorities. From a practical perspective, the developed tool provides value for system integrators, architects, and designers by simplifying the selection process and ensuring that proposed solutions match end-user expectations. For households, the application reduces the need for technical expertise, thus encouraging wider adoption of energy-efficient smart home solutions.

Study limitation—the limited sample size of users during the testing phase, which in the future could be expanded by conducting applied research across different demographic segments.

This methodology ensures that the decision regarding the selection of a home management system is well-founded, understandable, and effectively adaptable to each user's individual needs.

The proposed building management system selection criteria and selection principle can be integrated into decision support systems, which would help designers, architects, and system integrators make well-founded decisions.

5. Conclusions

This study developed a personalized decision-making system for selecting smart home management solutions in the context of nearly Zero Energy Buildings (nZEB). The mobile application, based on a structured questionnaire and the Simple Additive Weighting (SAW) method, helps users objectively evaluate functional priorities and receive tailored recommendations. The prototype was tested with JUNG solutions; however, the decision-making logic is universal and applicable to any smart home management system that meets the defined criteria.

The main limitation of the study is the small testing sample, which should be expanded through broader empirical research across diverse demographic groups. Future development directions include interactive product comparisons, a preliminary cost calculator, 3D visualizations, adaptive questionnaire logic, and options to export or share recommendations.

The proposed tool addresses key challenges of user engagement, decision personalization, and energy efficiency. Beyond end-user support, it also provides value to architects, designers, and system integrators by offering a structured framework that links user needs with technological solutions, facilitating more efficient project planning and communication with clients.

The novelty of this work lies in the fact that the developed solution for the first time systematically combines the technical analysis of smart home management systems (SHMS) with the personalization of user needs. Previous studies have mainly focused on the optimization of technological parameters (e.g., energy efficiency, IoT integration, security aspects) but have poorly analyzed how the end user makes decisions and what measures can reduce uncertainty when choosing a system.

The methodology proposed in this study fills this gap—using a structured questionnaire and the SAW method, conditions are created for personalized selection, when user priorities become the main criterion in the decision logic. The tool created in this way not only makes technical parameters understandable to the user but also provides an opportunity to practically apply personalized decision support.

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Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial Intelligence
BIM	Building Information Modelling
BMS	Building Management System
HVAC	Heating, Ventilation, and Air Conditioning
IoT	Internet of Things
JWT	JSON Web Token
nZEB	nearly Zero Energy Buildings
RBAC	Role-Based Access Control

RES	Renewable Energy Sources
REST API	Representational State Transfer Application Programming Interface
SAW	Simple Additive Weighting
SHMS	Smart Home Management System

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