POLITECNICO DI TORINO

Master's Degree in Computer Engineering

Master's Degree Thesis

Design and Evaluation of an Innovative User Interface for an Integrated Smart-Home System

Supervisor

Prof. Luca ARDITO

Candidate

Ghazal GHORBANI

December 2025

Abstract

The growing diffusion of smart home systems has given central importance to user interfaces, which must combine simplicity, reliability, and an engaging user experience. This thesis aims to design and evaluate a mobile application for managing an integrated home automation system, including the control of lights, smart sockets, room temperature control, shutters and blinds, cooling systems, and alarm systems. After a context analysis and a critical review of the literature and existing solutions, the design principles guiding the development of an innovative, graphically refined, and intuitive interface will be outlined. The prototype will be evaluated through questionnaires and user tests, with the aim of assessing usability, clarity, perceived satisfaction, and degree of innovation compared to current standards. This work aims to contribute to research on the design of interfaces for home automation by proposing a user experience model that is both functional and aesthetically pleasing.

Acknowledgments

I would like to express my deepest gratitude to everyone who accompanied me throughout this journey and made the completion of this Master's thesis possible.

First and foremost, I extend my sincere thanks to my supervisor, Professor Ardito, whose guidance, expertise, and patience have been invaluable. His encouragement and insightful feedback have shaped both this work and my growth as a designer.

My warmest appreciation goes to my family, who have been my foundation. Thank you for your unconditional support, constant encouragement, and for believing in me even during the most challenging moments. Your love kept me motivated.

To my friends, thank you for the laughter, conversations, and much-needed breaks that helped me stay balanced. Your presence made this journey lighter and more joyful.

A heartfelt thank-you to my boyfriend for his unwavering support, understanding, and kindness. Thank you for standing by me, for your patience during long days of work. Sharing this long journey with you has made even the most challenging moments bearable.

To all of you—thank you for being part of this milestone. I am deeply grateful.

Ghazal Ghorbani

Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

1.1 Background

In recent years, the smart-home sector in Italy has undergone significant growth, reflecting the country's increasing interest in digital technologies aimed at improving domestic comfort, security, and energy efficiency. According to the latest joint research by the Internet of Things Observatory of the Politecnico di Milano and BVA Doxa, approximately six out of ten Italians now own at least one smart device in their homes. Specifically, about 59% of consumers report owning connected products, while 41% have successfully integrated them into their home networks
[1]. Awareness of the "smart home" concept has also expanded considerably, with 69% of Italians claiming familiarity with the term—an increase of nearly ten percentage points compared to 2023
[1] [2].

Despite this strong diffusion, a gap remains between ownership and effective integration: only about four in ten Italian users with smart devices have configured them to function as part of a unified system. Recent data show that mobile applications are becoming the main interface between users and their

smart environments. Approximately 72% of users control their smart-home devices through dedicated apps, and 87% of these individuals use such apps at least once or twice per week. Notably, 72% report using them daily, with most evaluating their usability positively, rating them four or five out of five for ease of use
[1].

Market data from the Internet of Things Observatory and Fantini Cosmi (2024) highlight that the Italian smart-home market is primarily driven by four segments: home security systems (24%), smart appliances (19%), climate control devices such as heating and air conditioning (18%), and smart speakers or voice assistants (16%). Energy-related solutions—including connected boilers, heat pumps, and thermostats—remain highly relevant, even following the reduction of fiscal incentives. About 17% of Italian consumers explicitly associate smart-home technologies with energy management, while 24% consider real-time energy monitoring among the most valuable future functions [2].

These findings indicate that the typical Italian smart-home user focuses on four core goals: improving domestic security, simplifying daily tasks through automation, enhancing comfort through environmental control, and reducing energy consumption. Nevertheless, academic research suggests that the Italian smart-home ecosystem remains fragmented. The study by IUAV University describes a context in which households often rely on multiple, brand-specific applications, rather than a single unified control platform. This fragmentation poses usability challenges and highlights the need for more integrated design solutions [3] .

From a market perspective, the Internet of Things Observatory (2025) estimates that the Italian smart-home market reached approximately €900 million in 2024, marking an 11% increase from 2023. Although per-capita spending in Italy (about €15.5 per inhabitant) remains below the European average (€32.5), the steady upward trend confirms a growing demand for smart-home solutions. In the Internet of Things (IoT) ecosystem, Italy counted around 155 million connected devices in 2024—an average of 2.6 per inhabitant—demonstrating that connected technologies are now somehow an inseparable part of daily life [4].

International forecasts corroborate this domestic growth. A recent report by NextMSC values the Italian smart-home market at approximately USD 3.39 billion in 2023, with projections reaching USD 12.58 billion by 2030—an estimated compound annual growth rate (CAGR) of 20.6% [5]. Similarly, Mordor Intelligence (2025) estimates that the market will grow from USD 2.54 billion in 2025 to USD 4.14 billion by 2030, reflecting a more conservative CAGR of around 9.8% [6]. Despite variations across methodologies, these studies collectively confirm that Italy's smart-home sector is entering a dynamic phase of expansion, driven by increasing consumer adoption and technological advancement.

1.2 The Smartotum Application

Smartotum is an Italian smart-home platform that integrates home automation, energy management, and security functionalities into a single, intuitive system [7]. Developed by an Italian technology company and spin-off initiative from the Politecnico di Torino, Smartotum seeks to make home automation accessible to everyone through an innovative, wireless solution that does not require structural renovation [8]. Its guiding philosophy is summarised on its official website through three core principles: *one app for all functions, no renovation required, and guaranteed privacy* [7].

The platform is designed for homeowners and residents who wish to control and monitor their living spaces in a simple, secure, and modular way. Unlike many international smart-home systems that depend on external cloud infrastructures, Smartotum emphasises user data protection and system reliability by ensuring that all data remains within the home network. This "local-first" approach reflects a growing sensitivity among European consumers toward privacy and technological independence [9]. It positions Smartotum as a distinctive alternative to global ecosystems such as Amazon Alexa, Google Home, or Apple HomeKit, combining the convenience of connected living with full control over one's personal information.

Functionally, Smartotum enables the management of lighting, motorised blinds, electrical sockets, appliances, climate control, and security systems. It supports advanced routines that automate everyday actions—for example, activating alarms when the user leaves home. The system also provides real-time monitoring of energy consumption and offers compatibility with major voice assistants, allowing both manual and voice-based control. Because the platform operates wirelessly, installation is non-invasive and scalable, making it adaptable to both new constructions and existing buildings, including older or historic homes that dominate much of Italy's residential landscape [10].

From a technical standpoint, Smartotum relies on a distributed network of devices and hubs that communicate without external dependencies, ensuring stability even when internet connectivity is interrupted. Its modular architecture allows homeowners to begin with a basic setup and expand functionality over time as their needs evolve. This flexibility aligns with Italian market preferences for gradual, customisable upgrades rather than full-scale renovations.

In addition to its functional and technical aspects, Smartotum communicates a clear set of **brand values**. It presents itself as *innovative, private, and human-centered*—a technology that adapts to the home rather than requiring the home to adapt to technology. The brand's visual identity conveys these values through clean, modern typography, a minimal aesthetic, and soft, balanced colours that evoke simplicity and domestic comfort. The tone of its communication focuses on trust, independence, and ease of living: Smartotum promises to "make homes intelligent, not intrusive." This positioning differentiates it from other market players by combining Italian design sensibility with technological rigor and ethical awareness about digital privacy.

Overall, Smartotum represents an Italian approach to smart-home innovation that balances functionality, aesthetics, and respect for personal data. Its wireless flexibility, modular system, and unified interface offer a vision of accessible, human-centered domestic technology—an example of how design and engineering can coexist to create a more secure and comfortable living environment.

1.3 Problem Statement

Although Smartotum provides an innovative and privacy-oriented approach to home automation, its current application exists only as a basic functional prototype with limited attention to user experience and interface design. The app successfully demonstrates the core technological features of the Smartotum system—such as controlling lighting, climate, and security—but lacks the cohesive structure, visual hierarchy, and interactive clarity required for everyday usability. Without a well-developed interface, users may struggle to understand available functions, navigate efficiently, or perceive the brand's intended values of simplicity, privacy, and comfort.

In the competitive smart-home market, where design quality and ease of interaction are decisive factors in user adoption, these limitations could significantly reduce Smartotum's potential to reach and retain a wider audience. The absence of an intuitive UI/UX framework also hinders the company's ability to communicate its core principles—accessibility, modularity, and data independence—through a seamless digital experience.

As a result, this research addresses the need to design a complete, user-centered interface for the Smartotum application. By applying the Design Thinking methodology, the study seeks to identify user expectations within the Italian smart-home context and translate them into an interface that is both functional and emotionally engaging. The goal is to ensure that Smartotum's technological strengths are supported by a clear, coherent, and human-centered digital experience that reflects its brand vision and enhances everyday interaction with the smart home.

1.4 Research Objectives

The main objective of this research is to apply the Design Thinking methodology to develop a user-centered redesign of the Smartotum smart-home application, transforming its current functional prototype into an intuitive and visually coherent interface. The study aims to align the app's design with Smartotum's brand values of simplicity, privacy, and accessibility while enhancing usability and user satisfaction.

More specifically, the research pursues the following objectives:

1. To investigate the needs, expectations, and behaviors of potential Italian smart-home users through qualitative research and competitor analysis.
2. To identify key usability challenges and opportunities in the existing Smartotum application and define clear design requirements.
3. To generate and evaluate interface concepts using Design Thinking's iterative phases — Empathize, Define, Ideate, Prototype, and Test.
4. To produce a refined high-fidelity prototype of the Smartotum app that demonstrates improved usability, navigation, and aesthetic coherence.
5. To assess the redesigned interface through user testing and feedback to measure its effectiveness and perceived value.

By addressing these objectives, the research seeks to bridge the gap between Smartotum's technological functionality and an engaging, human-centered digital experience that supports the growing adoption of smart-home systems in Italy.

1.5 Research Questions

This thesis studies two main research questions that reflect both the methodological and design-oriented aims of the project:

1. How can the Design Thinking methodology be applied to enhance the user experience and usability of the Smartotum smart-home application?
2. What are the most essential UI and UX improvements required to make the Smartotum app more accessible, intuitive, and aligned with the needs of Italian smart-home users?

1.6 Scope and Contributions

1.6.1 Scope of the Study

The scope of this research is limited to the design and evaluation of the Smartotum mobile application interface; it does not include technical development, coding, or hardware integration of the system. The target context is the Italian smart-home market, with an emphasis on the needs, preferences, and behaviors of potential domestic users. The outcomes are design-oriented rather than commercial, focusing on usability, aesthetics, and interaction quality within the boundaries of a design research framework.

1.6.2 Contribution of the Study

The study contributes to both academic and practical understandings of user-centered design in the context of smart-home technologies. Academically, it demonstrates how the Design Thinking methodology can be systematically applied to guide interface design for emerging IoT systems, bridging theory and practice. Practically, it provides Smartotum with a comprehensive design solution and a set of actionable guidelines that can support the future development of its mobile application. More broadly, the research offers insight into how privacy-focused and modular smart-home systems can be designed to meet Italian users' expectations for simplicity, comfort, and control. The outcomes thus contribute to the wider discourse on human-centered technology and to the growing body of knowledge surrounding UX design for smart-home applications.

1.7 Methodological Framework

This thesis adopts the **Design Thinking methodology** as the guiding framework for the research and design process. Design Thinking is a human-centered, iterative approach to problem-solving that combines analytical and creative thinking to develop solutions based on real user needs [11]. The process is structured around five sequential but flexible phases — **Empathize, Define, Ideate, Prototype, and Test** — which together form a cyclical framework for innovation.

In this research, each phase corresponds to a distinct chapter of the thesis. The *Empathize* phase investigates the context, existing smart-home interfaces, and user pain points through literature review and benchmarking. The *Define* phase translates those findings into user personas, problem statements, and design requirements. The *Ideate* phase explores potential solutions through information architecture, sketches, and wireframes. The *Prototype* phase develops a high-fidelity interactive interface reflecting the proposed design principles. Finally, the *Test* phase evaluates the prototype through user testing and questionnaires to assess usability, satisfaction, and innovation.

The overall methodological flow of the study is summarized in **Figure 1.1**, which visually represents the five Design Thinking phases and their correspondence to the thesis chapters.

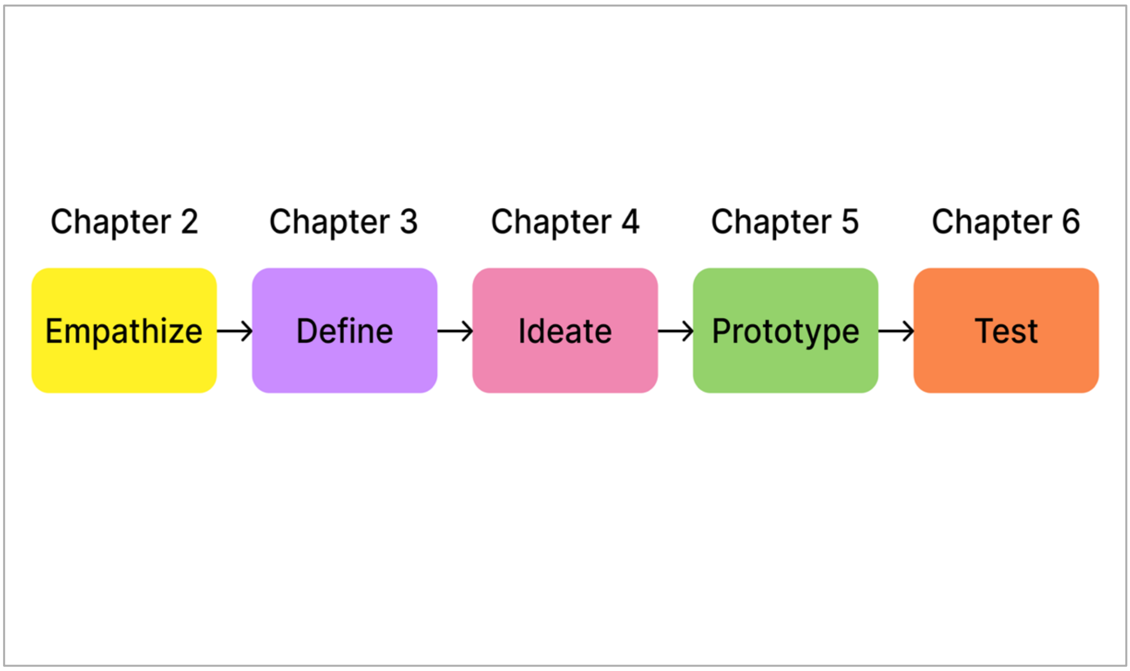

Figure 1.1: Process roadmap mapping the thesis chapters to Design Thinking phases

1.8 Thesis Structure

This thesis is organized into the following chapters:

1. Introduction – Presents the background, problem statement, research objectives, scope, contributions, and overall structure of the study.
2. Empathize – Contextual Analysis and State of the Art – Reviews literature on smart home interfaces, benchmarks existing applications, and analyzes user needs.
3. Define – Design Principles and Requirements – Establishes the design principles, personas, and user scenarios that inform the prototype.
4. Ideate – Concept and Wireframes – Describes the ideation process, information architecture, wireframes, and user flows.
5. Prototype – Interface Development – Details the high-fidelity UI design, interactive Figma prototype, and visual coherence.

6. Test – User Evaluation – Explains the usability testing methodology, participant recruitment, data collection, and metrics.
7. Results and Discussion – Analyzes usability results, satisfaction, clarity, and compares the prototype with existing standards.
8. Conclusions and Future Work – Summarizes contributions, discusses limitations, and provides recommendations for future research.
9. References – Lists all sources cited throughout the thesis.
10. Appendices – Includes the questionnaire, personas, wireframes, prototype screens, and usability test data.

Chapter 2

Empathize – Contextual Analysis and State of the Art

2.1 Literature Review on Smart-Home Interfaces

The evolution of smart-home technologies has progressively shifted attention from connectivity and automation toward the quality of user interaction with intelligent environments. A smart home is defined as a residence equipped with networked technologies that provide personalized services for users [12]. This perspective highlights that technological advancement alone does not determine adoption; rather, the effectiveness of the interface—how users control and understand their systems—is a key factor influencing satisfaction and long-term engagement [12].

Within this framework, the user interface (UI) of smart-home applications represents the main point of interaction between users and complex device ecosystems. Research increasingly identifies interface design as a critical determinant of usability and acceptance. Yu et al. conducted an empirical study on control components within smart-home dashboards and found that specific interface characteristics, such as larger button sizes and horizontal slider orientation, significantly improved task completion time and reduced cognitive load, particularly for older users. Their findings demonstrate that micro-level interface elements can have a measurable impact on performance and accessibility [13].

Accessibility and inclusivity have also emerged as central themes in the design of smart-home interfaces. According to Fakhimi et al., older adults encounter significant challenges when interacting with smart-home applications, mainly due to interface complexity, inconsistent feedback, and limited customization options. Their review highlights that inclusive design—incorporating multimodal interaction such as voice and touch—can mitigate these barriers and improve overall usability for diverse user groups [14]

A related body of work explores how smart-home interface design must align not only with usability principles but also with user values and perceptions of control. Samancıoğlu (2024) examined the relationship between technology attributes and user preferences, emphasizing that successful adoption depends on interfaces that express transparency, simplicity, and respect for privacy. The study concludes that users tend to evaluate smart-home systems through the lens of perceived autonomy and trust—dimensions that are directly mediated through interface design [15].

Across these studies, a consistent pattern emerges: smart-home interfaces must support intuitive navigation, minimize cognitive effort, and visually communicate system status and feedback in a clear and consistent manner. They must also be adaptable to different user profiles and needs, providing an inclusive experience across age groups and levels of technological familiarity. Furthermore, by reflecting values such as privacy, simplicity, and reliability, interface design plays an essential role in fostering user trust and emotional comfort within the connected home.

In summary, while much of the research on smart-home systems has traditionally concentrated on technical infrastructures and device interoperability, the interface layer remains the most immediate and human dimension of the smart home. Well-designed interfaces not only enhance usability and satisfaction but also determine the extent to which users feel in control of their environment. The literature, therefore, positions user-interface design as a strategic factor in the success of smart-home technologies, highlighting the need for human-centered approaches to interface development.

2.2 UX Principles for Smart Home Applications

User Experience (UX) design in smart-home systems goes beyond appearance to include how effectively and efficiently users can interact with their connected devices. Interfaces must bridge complex device ecosystems and present them in meaningful ways. A foundational resource in interaction design argues that good design is fundamentally about creating understandable and usable systems rather than simply attractive ones [16].

A core principle is **usability**, which encompasses learnability, efficiency, memorability, error-tolerance, and satisfaction. These attributes are especially critical in smart-home apps where users manage multiple devices through a single interface. Jakob Nielsen's usability heuristics provide a practical foundation for smart-home interface evaluation: for example, *visibility of system status* (users should always know what the system is doing) and *consistency and standards* (interface elements should behave predictably) [17].

Another principle is **navigation clarity and task flow optimisation**. Smart-home apps often involve frequent tasks (turning devices on/off, scheduling automation, checking statuses), and users benefit when flows are streamlined. For example, in a study of slider controls in smart-home dashboards, Yu et al.

found that horizontal sliding orientation and larger button size significantly improved task completion time and reduced cognitive load [13].

Feedback and system status indication is also essential in the smart-home domain. When users issue commands (e.g., switching lights on, setting a routine) the system must provide a clear acknowledgement that the action succeeded, failed, or is pending. Inconsistent or missing feedback leads to confusion and decreased trust in automation. A design guideline document for home-automation web interfaces emphasises that feedback loops (visual, auditory, or haptic) and clear status markers are vital to maintain user trust and control [18].

Visual hierarchy and minimal cognitive load play a further role. Smart-home users frequently navigate many functions and devices; therefore, the interface should support quick recognition of important tasks, reduce clutter, and use iconography and typography that users understand without effort. The "aesthetic-usability effect" suggests that users tend to judge visually appealing interfaces as easier to use [19]. Although this effect is more widely studied outside smart homes, its implication is that minimal, well-organised UI can contribute to perceived usability.

Finally, **flexibility and adaptability** matter in smart-home environments. Users may have different routines, devices, and levels of engagement. Interfaces should allow customization (e.g., favourite devices, grouped scenes) and adapt to user contexts (e.g., quick access to frequently used scenes). Research on smart-home dashboards indicates that interface components (such as sliders, toggles, scenes) must be designed with flexibility so users can tailor their environment without being constrained by rigid structure [13].

In summary, key UX principles for smart-home applications include:

- ensuring high usability (learnability, efficiency, satisfaction)
- providing clear system status and feedback

- optimising navigation and task flows
- designing minimal cognitive-load visual hierarchies
- enabling flexibility and adaptation to user behaviours

These principles provide a theoretical basis for designing a smart-home app interface that is intuitive, efficient, and aligned with user task-oriented environments, without focusing specifically on elderly users or privacy concerns.

2.3 Benchmark of Existing Smart Home Apps

A heuristic desk review was conducted on widely used smart home apps selected for multi-device integration and market relevance (Amazon Alexa, Google Home, Apple Home (HomeKit), Philips Hue, Eve). A comparative matrix (Table 2.1) summarizes their key capabilities, illustrating how well each app supports core smart-home functions and user interaction patterns.

The evaluation followed a heuristic, expert-review approach grounded in Nielsen's usability heuristics and the UX principles outlined in Section 2.2.

Table 2.1: Summary of common capabilities

Capability	Alexa	Google Home	Apple Home	Hue	Eve
Room-centric dashboard	✓	✓	✓	~	~
Quick global actions (e.g., All off / All shutters down)	~	~	✓	✗	~
Guided routine/scene setup	~	~	✓	✗	~
Schedules (lighting/heating)	~	✓	✓	✓	✓
State feedback + confirmations/toasts	~	✓	✓	✓	~

✓ clearly present and easy to use; ~ partially present or hard to find; ✗ missing.

The following analysis summarizes navigation, feedback, automation, visual design, and accessibility across apps, highlighting strengths and weaknesses that inform design choices.

The evaluation criteria were derived from the UX principles outlined previously (simplicity, clarity, consistency, feedback, accessibility, and aesthetic appeal). The main aspects considered during the benchmarking were:

1. **Ease of Navigation**
    - Amazon Alexa: The app is heavily menu-driven, with navigation primarily through tabs such as Devices, Routines, and Skills. While functional, frequent switching between screens can be confusing for new users.
    - Google Home: Provides a visually clear home dashboard showing connected devices and rooms. The structure is simple, but adding new devices or accessing advanced settings may require multiple steps.
    - Apple Home: Emphasizes a minimalist design with a focus on rooms and scenes. Navigation is straightforward, and the interface leverages native iOS patterns, which can be intuitive for iPhone users.
    - Philips Hue & Eve: Offer clear device grouping and simple control for lighting and smart plugs, but their app experience is sometimes fragmented when integrating third-party devices.
2. **Device Control and Feedback**
    - Amazon Alexa: Offers voice control as the primary interaction, supplemented by the app. Visual feedback is sometimes limited, making it harder to confirm actions performed via voice.
    - Google Home: Provides immediate visual feedback for most device actions (e.g., lights on/off, thermostat adjustments) with clear status indicators.

- Apple Home: Displays real-time device status in each room, providing reliable feedback for user actions.
- Philips Hue & Eve: Lighting control is responsive, with clear visual indicators of device state; however, controlling multiple devices simultaneously can be cumbersome.

3. Automation and Scenario Management

- Amazon Alexa: Supports complex routines and integrations across third-party devices. However, creating and editing routines may be unintuitive for non-technical users due to nested menus and limited guidance.
- Google Home: Offers automation through "Routines" and conditional triggers (e.g., time, device state). Setting up routines is more straightforward than Alexa but still requires learning the available triggers and actions.
- Apple Home: Provides a visually guided scene and automation setup that is more user-friendly, leveraging a step-by-step approach. Users can combine multiple devices in scenes efficiently.
- Philips Hue & Eve: Allow room-based automations and schedules, but complex multi-device automations are less accessible due to limited workflow visualization.

4. Visual Design and Aesthetics

- Amazon Alexa: Functional design, but visually dense; prioritizes functionality over aesthetic coherence.
- Google Home: Clean and modern interface with consistent use of colors and typography; presents devices in card-style layouts for readability.
- Apple Home: Minimalist design aligned with iOS standards; emphasizes clarity, whitespace, and intuitive icons.

- Philips Hue & Eve: Focus on functional clarity for lighting controls; color coding helps, but aesthetic appeal varies across screens.

5. Accessibility and User Assistance

- Amazon Alexa: Offers voice interactions as a core feature, making it accessible to users with limited mobility. Onboarding and help resources are available but can feel fragmented.
- Google Home: Includes guided setup and contextual help tips; interface is generally intuitive for average users.
- Apple Home: Benefits from iOS accessibility features such as VoiceOver and dynamic text, ensuring usability for a wider audience.
- Philips Hue & Eve: Support basic accessibility, but advanced features may require external guidance or technical knowledge.

Findings and Insights

The benchmarking highlights several common strengths and weaknesses across prominent smart home apps:

- **Strengths to Emulate:**
  - Clear dashboards (Google Home, Apple Home) that prioritize room- or device-based organization.
  - Immediate feedback for user actions (Google Home, Apple Home, Hue) to ensure users feel in control.
  - Step-by-step guided automation setup (Apple Home) that simplifies complex tasks.
  - Voice integration (Alexa) for accessibility and convenience.
- **Weaknesses to Address:**

- Fragmented interfaces and multiple nested menus (Alexa, Hue) which can confuse users.
- Complexity in creating and managing automations (Alexa, Google Home, Hue) for non-technical users.
- Visual inconsistencies across screens, especially when integrating third-party devices.
- Limited contextual help and guidance for first-time users.

These insights provide a foundation for defining design requirements and priorities for the mobile application prototype. The goal is to combine the best usability practices observed in these apps while addressing their shortcomings, particularly by simplifying navigation, improving automation setup, ensuring visual consistency, and maintaining an intuitive, user-friendly interface.

2.4 Current Smartotum App – Baseline Review

The current Smartotum mobile application represents an early functional prototype focused primarily on system control rather than design aesthetics or interaction quality. The interface includes essential UI components such as buttons, icons, tabs, and dropdowns, but these are implemented with minimal visual hierarchy, spacing, or interaction feedback. The visual layout is composed of dark-blue and light-blue panels with a consistent flat design across screens; however, there is no clear distinction between primary and secondary actions, and the lack of contrast and typography variation reduces visual clarity.

Navigation is handled through a bottom tab bar with generic icons representing sections such as *Home*, *Rooms*, *Security*, *Climate*, *Analytics*, *Notifications*, and *Settings*. While this provides basic structure, the icons are not supported by labels, which can create ambiguity for first-time users. Additionally, the excessive number of navigation buttons may contribute to cognitive overload, as users must interpret multiple unlabeled symbols and remember their corresponding functions. The interface elements are mostly rectangular containers and lists without dynamic feedback or transitions.

Each screen delivers raw functional data: for example, the *Home* dashboard lists modules for climate, lights, shutters, alarm, and energy usage, displaying numerical values or simple on/off indicators. Other screens, such as *Security* and *Notifications*, present plain lists of sensor names or events without clear visual grouping or prioritization. Functional operations such as editing schedules, activating sensors, or viewing system messages are possible, but their interactions rely on static navigation and offer no confirmation animations or contextual guidance.

Overall, the current version demonstrates a functional proof of concept rather than a designed product. It effectively connects with the Smartotum system backend and executes core smart-home functions, but it lacks user-centered design elements such as hierarchy, consistency, accessibility, and aesthetic appeal. This state makes it a suitable baseline for redesign through the Design Thinking process, allowing the research to focus on transforming a purely technical interface into an intuitive and engaging user experience.

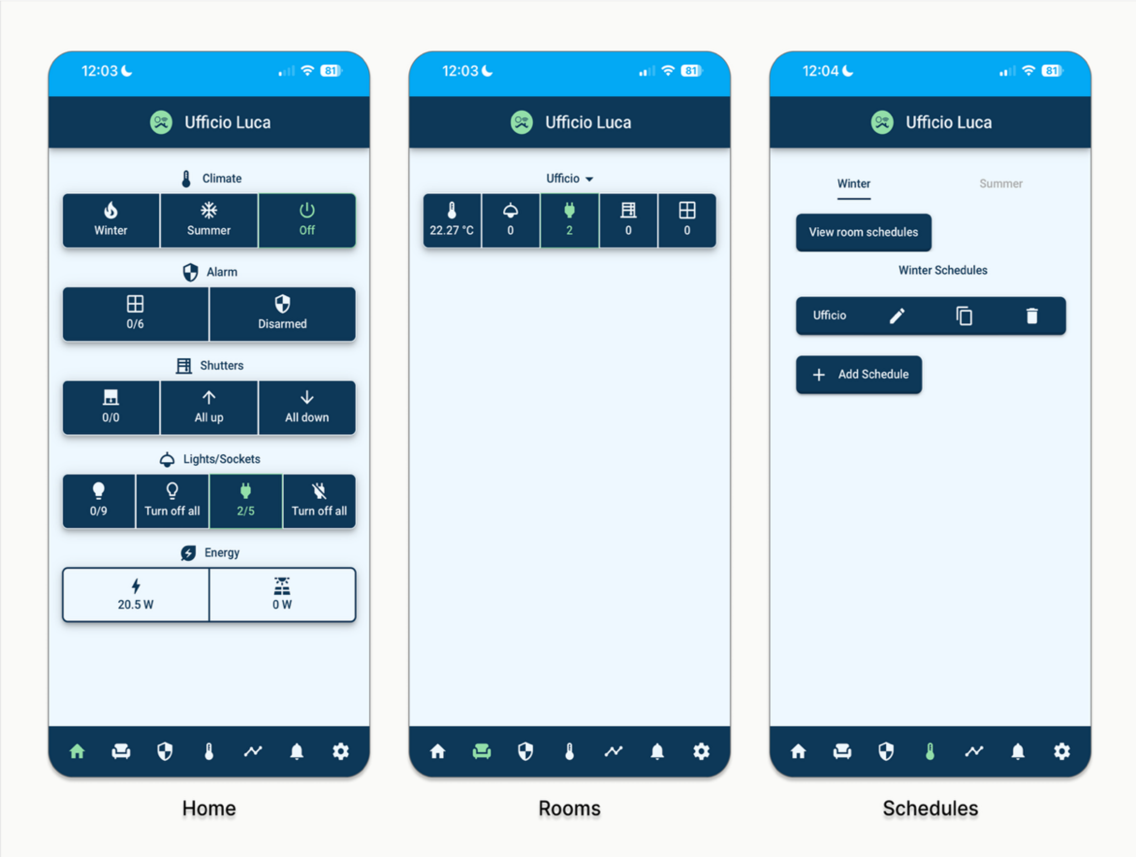

Figure 2.1: Main interface screens of the current Smartotum application. The *Home*, *Rooms*, and *Schedules* interfaces display the fundamental layout logic of the current system. Each screen maintains a consistent card-based structure and a uniform color palette. However, the lack of visual hierarchy, minimal use of affordances, and limited feedback indicators contribute to low perceived usability.

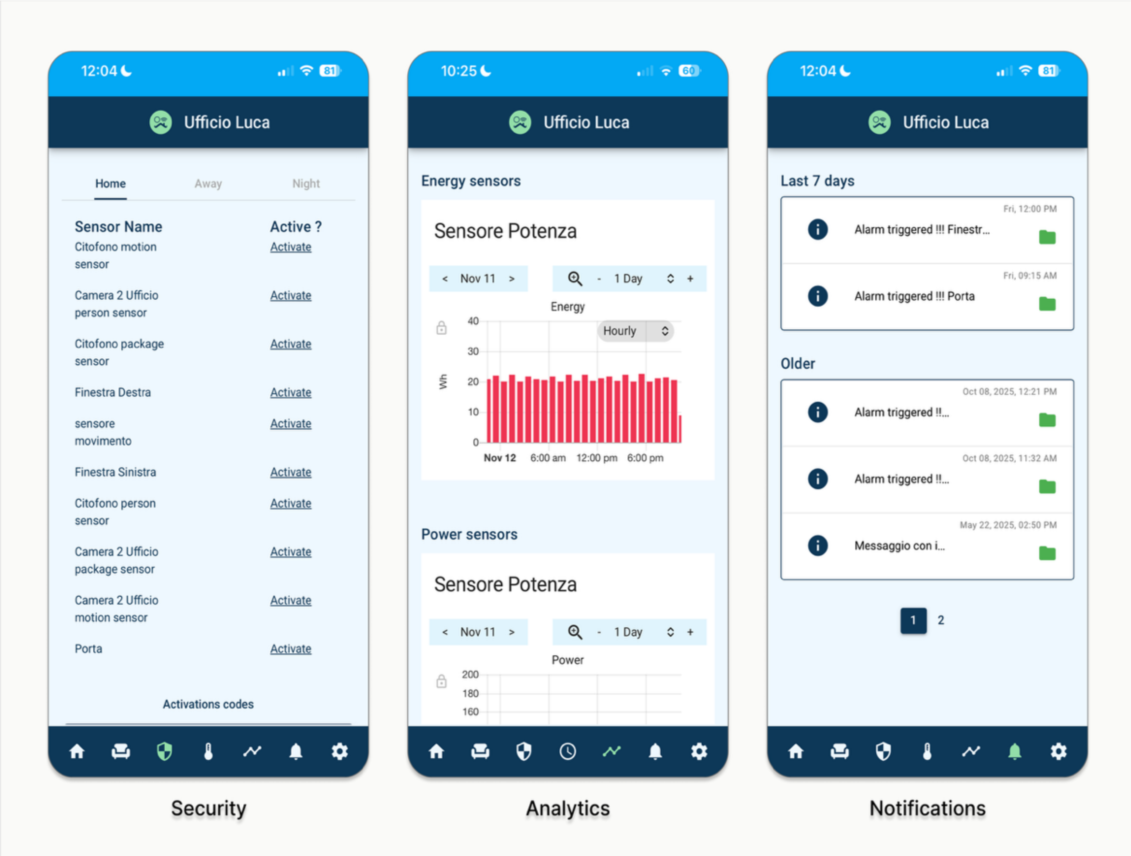

Figure 2.2: Secondary interface screens of the current Smartotum application. The *Security*, *Analytics*, and *Notifications* screens demonstrate the system's technical coverage but also reveal fragmentation in navigation and information organization. Excessive use of similar visual elements and icons without clear labeling reduces recognizability and may increase cognitive load for users.

Each screen delivers raw functional data: for example, the *Home* dashboard lists modules for climate, lights, shutters, alarm, and energy usage, displaying numerical values or simple on/off indicators. Other screens, such as *Security* and *Notifications*, present plain lists of sensor names or events without clear visual grouping or prioritization. Functional operations such as editing schedules, activating sensors, or viewing system messages are possible, but their interactions rely on static navigation and offer no confirmation animations or contextual guidance.

Overall, the current version demonstrates a functional proof of concept rather than a designed product. It effectively connects with the Smartotum system backend and executes core smart-home functions, but it lacks user-centered design elements such as hierarchy, consistency, accessibility, and aesthetic appeal. This state makes it a suitable baseline for redesign through the Design Thinking process, allowing the research to focus on transforming a purely technical interface into an intuitive and engaging user experience.

2.5 User Needs and Pain Points

The analysis of existing literature, UX principles, benchmarked smart-home applications, and the current Smartotum prototype reveals several converging themes concerning user needs and usability challenges in the smart-home domain. These findings define the foundation for the subsequent design and prototyping phases.

2.5.1 User Needs

Smart-home users seek an experience that is **intuitive, efficient, and reliable**, enabling them to manage multiple connected devices without technical barriers. Across studies and market observations, users consistently express the need for:

- **Simplicity of control:** the ability to perform common actions such as switching off all lights, adjusting temperature, or checking system status with minimal navigation effort.
- **Clarity and visibility:** clear representation of rooms, devices, and states, supported by immediate feedback confirming system responses.
- **Consistency and predictability:** coherent use of icons, colors, and interaction patterns that reduce the learning curve and allow users to transfer knowledge between tasks.

- **Task-oriented navigation:** dashboards organized around spaces (rooms) or activities rather than device brands or categories, facilitating quick orientation.
- **Aesthetic coherence:** interfaces that appear visually balanced, pleasant, and aligned with users' expectations of modern smart-home design.
- **Customizability:** options to tailor dashboards or shortcuts to personal routines, enhancing perceived usefulness and comfort.

These needs correspond closely to the core UX principles discussed in Section 2.2—usability, visibility, consistency, feedback, and aesthetic clarity—confirming that users value control and comprehension as much as automation itself.

2.5.2 Pain Points

In contrast, the benchmark analysis and baseline review of the current Smartotum app highlight a series of usability shortcomings that hinder smooth interaction:

- **Cognitive overload from excessive navigation elements,** particularly the numerous icons in the navigation bar without textual labels.
- **Limited feedback mechanisms,** where users receive little confirmation after performing actions or changing system states.
- **Lack of visual hierarchy and grouping,** making it difficult to distinguish between primary and secondary functions.
- **Fragmented interaction flow,** requiring multiple steps to access core features such as automation or scheduling.
- **Absence of visual identity,** resulting in an interface that communicates functionality but not clarity or emotional appeal.

- **Low discoverability of advanced options,** such as creating scenes or schedules, due to static layouts and minimal guidance.

These findings indicate that while Smartotum's current version fulfills basic functional requirements, it does not yet provide the usability and engagement level expected in contemporary smart-home experiences.

Chapter 3

Define – Design Principles and Requirements

3.1 Introduction to the Define Phase

The Define phase represents the second stage of the Design Thinking process and builds directly upon the insights gathered during the Empathize phase. Its main objective is to synthesize research findings into clear, actionable definitions of user needs and design challenges. Whereas the Empathize phase focused on understanding the smart-home context, reviewing the literature, and analyzing existing applications, this stage translates those observations into structured problem statements and design requirements.

In the context of this thesis, the Define phase serves to clarify the key usability and interaction issues identified in the preliminary Smartotum application. It outlines the user personas, summarizes user needs, and formulates design principles that will guide the subsequent Ideate and Prototype phases. By defining the problem in precise and human-centered terms, this chapter establishes a coherent foundation for the development of an intuitive, efficient, and visually consistent smart-home interface.

3.2 Synthesis of Empathize Insights

The Empathize phase provided a detailed understanding of the Italian smart-home market, user expectations, and the strengths and weaknesses of existing applications. From the literature review, benchmarking, and the analysis of the current Smartotum prototype, several recurring themes emerged that define the main design opportunities for improvement. These insights focus on how users interact with smart-home systems and what principles should guide the redesign process.

Navigation and Information Structure

Navigation was found to be one of the most significant factors influencing usability in smart-home apps. Successful interfaces, such as those of *Google Home* and *Apple Home*, organize devices and controls according to rooms or tasks, allowing users to understand the system's structure at a glance. In contrast, Smartotum's current navigation relies on numerous unlabeled icons and a flat structure that requires users to explore each section to locate specific functions. This increases cognitive load and hinders first-time use. A more intuitive, room- and activity-based organization with clear visual hierarchy is therefore necessary.

Feedback and System Status Visibility

Providing immediate and unambiguous feedback emerged as a key usability requirement. Literature and benchmarking show that clear visual feedback — for instance, animations, color changes, or toast messages — builds user trust and prevents interaction errors. The current Smartotum prototype does not visually confirm user actions such as turning on a light or activating a schedule, which can cause uncertainty. Enhancing visibility of system status through consistent feedback mechanisms will improve perceived control and user confidence.

Automation and Task Management

Automation remains one of the most valued yet complex features of smart-home systems. Apps like *Alexa* and *Google Home* offer automation tools, but their configuration processes often require multiple steps and abstract logic. The Smartotum app currently lacks a guided workflow for creating or managing routines, limiting users to basic manual control. Simplified, visual, and step-by-step automation setup will support the brand's goal of intuitive smart-living management.

Visual Hierarchy and Aesthetic Coherence

Visual clarity and balance are essential for reducing cognitive load and improving engagement. The literature highlights that users often perceive visually clean interfaces as more usable — an effect known as the aesthetic–usability principle [19]. Smartotum's prototype uses consistent dark-blue tones and flat layouts, but with little contrast or hierarchy between elements. Establishing typographic variation, spacing rhythm, and consistent color hierarchy can help communicate structure and improve scannability.

Consistency and Brand Expression

Consistency in visual and behavioral patterns ensures predictability and familiarity, which are essential for user comfort. Benchmarking revealed that leading apps maintain coherence through standard iconography, consistent spacing, and unified motion design. Smartotum's current interface, while functionally cohesive, lacks alignment with its brand identity of "simplicity and connection." Introducing a coherent visual system that reflects Smartotum's values will reinforce usability and brand recognition simultaneously.

3.3 User Personas

To better define the target audience and contextualize user needs identified during the *Empathize* phase, two personas were developed based on insights from the smart-home market analysis, benchmarking results, and usability observations of the preliminary Smartotum interface.

These personas—**Giulia Bianchi** and **Marco Rossi**—represent two archetypal user profiles within the Italian smart-home ecosystem. They capture complementary usage patterns and expectations: Giulia as a technologically proficient professional seeking efficiency and control, and Marco as a comfort-oriented user who values simplicity and reliability.

The personas serve as a design reference throughout the *Ideate* and *Prototype* phases, ensuring that interface decisions remain aligned with real user goals, frustrations, and behavioral tendencies.

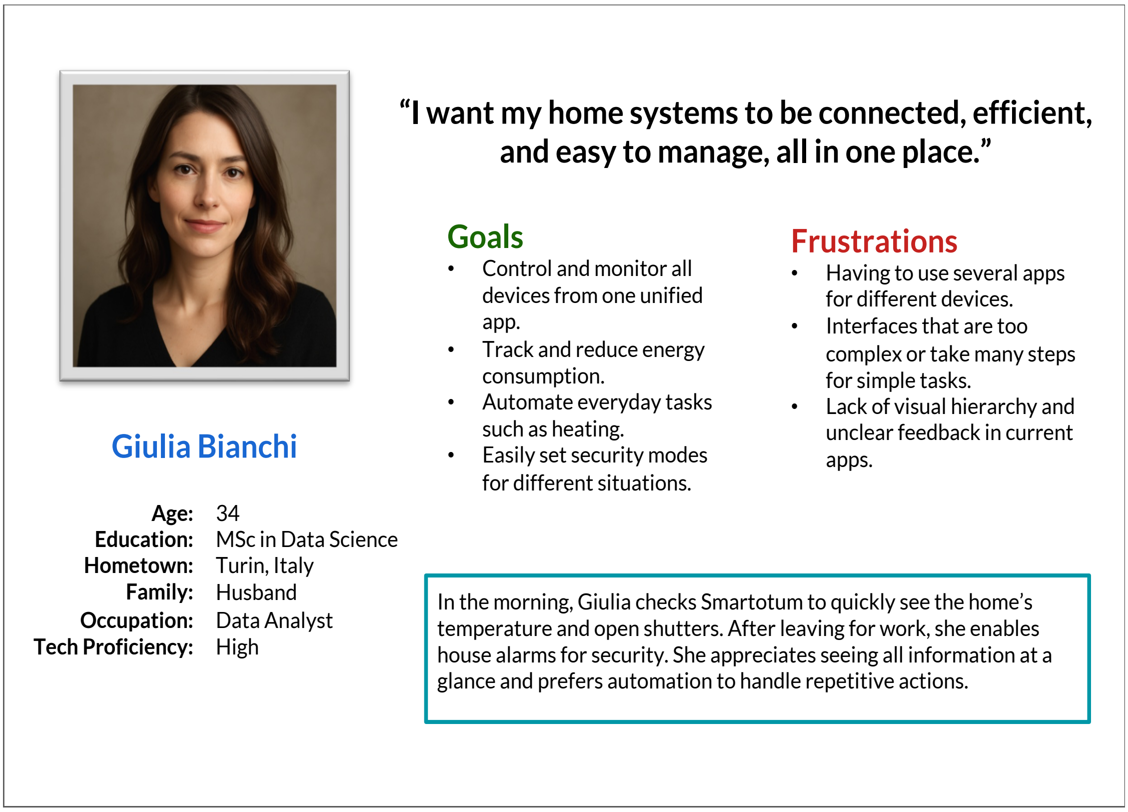

Figure 3.1: Persona 1: Giulia Bianchi, primary Smartotum user. Template adapted from the Google UX Design Certificate framework (Google Career Certificates, 2022). Photo generated by Sora.

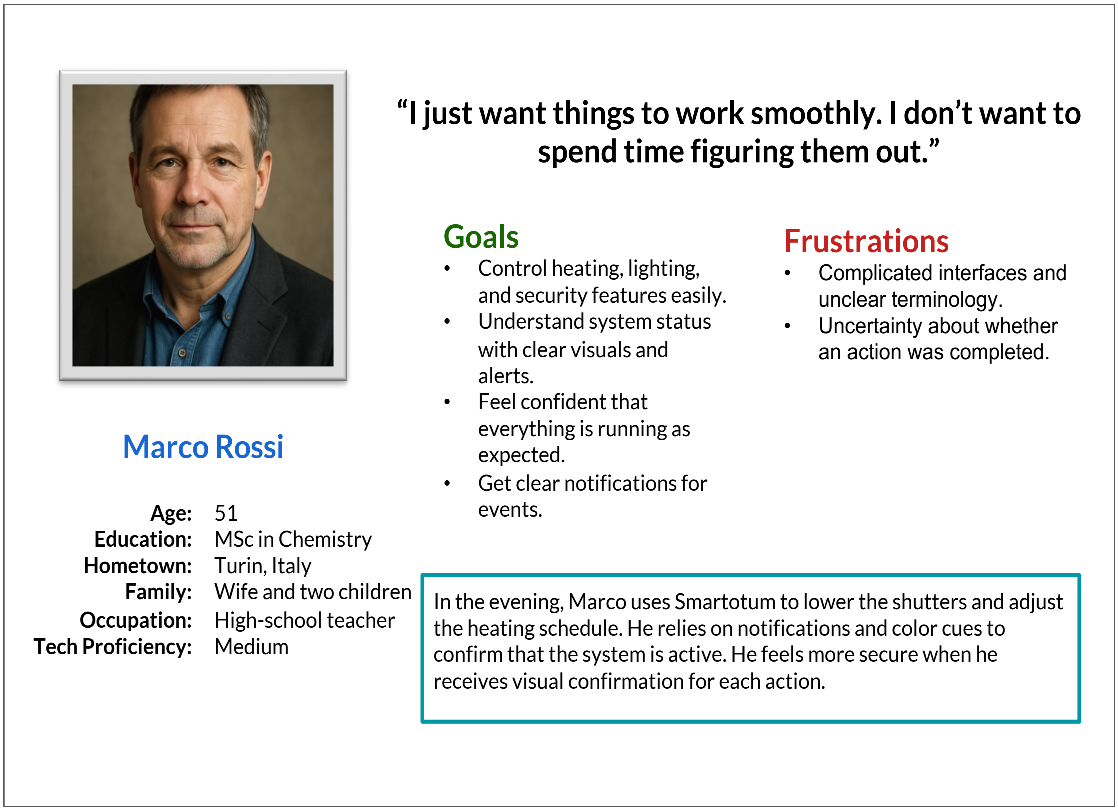

Figure 3.2: Persona 2: Marco Rossi, secondary Smartotum user.

Template adapted from the Google UX Design Certificate framework (Google Career Certificates, 2022). Photo generated by Sora.

The two personas illustrate distinct but complementary approaches to smart-home interaction. Giulia represents the efficiency-driven user, prioritizing automation, data visualization, and multi-device integration, whereas Marco embodies the usability-focused user, emphasizing clarity, reassurance, and straightforward control.

3.4 User Scenarios

The following scenarios illustrate how the two personas—Giulia Bianchi and Marco Rossi—interact with a smart-home system in typical daily contexts. They are based on the insights gathered during the *Empathize* phase, particularly the analysis of user needs, behavioral patterns, and common challenges identified through the literature review and benchmarking of existing applications.

Each narrative describes a realistic situation reflecting the users' motivations, goals, and frustrations. The scenarios provide a human-centered foundation for defining functional and design requirements in subsequent phases of the project.

Scenario 1 – Giulia: Morning Preparation and Routine Setup

Before leaving for work, Giulia checks the main dashboard of her smart-home application to ensure that all systems are functioning properly. She quickly reviews the status of lights, shutters, and indoor temperature. To optimize her energy use, she activates a "Leave Home" scene that automatically turns off non-essential devices.

Giulia then reviews her weekly energy-consumption summary and notes a slight reduction compared to the previous week. The clear and concise presentation of data helps her feel in control and reassured that her settings are working efficiently.

Design implication: the interface should allow users to perform key tasks—such as activating scenes or reviewing energy data—quickly and with minimal navigation effort.

Scenario 2 – Giulia: Responding to a Weather Alert Notification

During the afternoon, while working at the office, Giulia receives a notification from Smartotum:
"It's getting windy out there, do you want to close all shutters?"
Without needing to open the app, she taps "Yes" directly from the notification. The system immediately executes the action, closing all shutters remotely. A confirmation message appears—*"All shutters closed"*—giving her instant reassurance that her home is protected from the strong wind.

Design implication: Actionable notifications should enable users to perform simple, high-priority tasks directly, reducing interaction time and strengthening the sense of control and reliability.

Scenario 3 – Marco: Evening Comfort and Device Control

After dinner, Marco opens the app to adjust the lighting and temperature. He prefers straightforward, visible controls that indicate which devices are active. He activates the "Night" security mode, which he has previously created for securing the house at night. The color changing of the button, and the message "Armed – Night" reassure him that his home is protected before going to bed.

Design implication: frequently used actions should be represented by large, clearly labeled elements supported by immediate visual feedback.

Scenario 4 – Marco: Creation of Schedules

On Saturday morning, Marco creates his heating schedule for the winter season ahead. He prefers a simple interface that allows easy modification of time slots without complex forms. The visual overview of active schedules helps him ensure that the settings reflect his needs for comfort and energy efficiency.
Design implication: scheduling and configuration tasks should be guided by visual clarity and direct manipulation, minimizing cognitive effort.

3.5 Design Principles

The design principles serve as the conceptual foundation for the Smartotum redesign, translating user needs and contextual insights into actionable guidelines for the subsequent Ideate and Prototype phases.
They are derived from the findings of the Empathize phase and the behavioral patterns observed through personas and user scenarios, as well as from established human–computer interaction literature [16], [20].
These principles ensure that the redesigned interface is both technically effective and human-centered, addressing users' expectations for clarity, reliability, and consistency.

1. Simplicity and Cognitive Ease

The system must minimize cognitive load by presenting information and actions in a clear and structured way. Each function should be easily discoverable without requiring prior technical knowledge. The interface should group related functions logically and avoid unnecessary complexity.

Rationale: Giulia values speed and efficiency, while Marco prefers ease and reassurance. Simple, predictable layouts enable both to interact confidently without confusion.

2. Visual Hierarchy and Readability

Content and controls must follow a clear visual hierarchy, guiding attention to the most relevant information first. Typography, spacing, and color contrast should distinguish between primary and secondary elements.
Rationale: As both users rely on quick scanning—Giulia for monitoring energy data and Marco for controlling comfort—the interface must make essential information instantly perceivable.

3. Consistency and Predictability

The system should use a coherent logic of navigation, terminology, and visual style across all sections. Repeated patterns of interaction (e.g., toggles, scenes, schedules) should behave identically in all contexts [20].
Rationale: Consistency reduces learning time and prevents user errors—especially important for Marco, who seeks reassurance and dislikes surprises in the interface.

4. Feedback and System Transparency

Every action should produce clear, immediate feedback confirming the result or notifying the user of an error. Visual changes such as color shifts, icon updates, or confirmation messages increase user trust and situational awareness [16].
Rationale: In the scenarios, both users rely on feedback to confirm successful actions—Marco when activating the Night mode.

5. Accessibility and Inclusiveness

The design must remain usable for individuals with varying levels of digital literacy and sensory abilities. Adequate contrast, readable font sizes, and comfortable touch targets ensure accessibility and inclusiveness in accordance with the Web Content Accessibility Guidelines (WCAG) [21]

Rationale: The contrast between Giulia's and Marco's technological proficiency demonstrates the importance of an inclusive interface that accommodates different user types.

6. Aesthetic Coherence and Brand Alignment
The interface should visually reflect Smartotum's core values—innovation, reliability, and simplicity—through a consistent color palette, restrained iconography, and balanced use of whitespace. A clean aesthetic reinforces perceived professionalism and trustworthiness. Aesthetic consistency contributes to usability, by improving perceived clarity and reducing visual noise [22].
Rationale: A coherent and modern aesthetic enhances the emotional connection between users and the product, supporting usability through familiarity and visual calm.

3.6 Functional and Non-Functional Requirements

Following the definition of design principles, this section formalizes the functional and non-functional requirements for the Smartotum application. The goal is to translate user needs and behavioral insights identified in the *Empathize* phase—and refined through personas and user scenarios—into clear development-oriented specifications that will guide the *Ideate* and *Prototype* phases.
The requirements focus on improving usability, visual coherence, and interaction efficiency within the app's ecosystem, ensuring alignment with Smartotum's core values of innovation, reliability, and simplicity.

3.6.1 Functional Requirements

Functional requirements define the specific tasks and operations the Smartotum app must enable users to perform.

They are derived from the user scenarios and aligned with the system's role as a centralized smart-home control hub.

ID	Requirement	Description	Source / Rationale
FR-01	**Dashboard Overview**	The user shall view the status of connected devices (lights,shutters, temperature, alarms) on a single dashboard.	Giulia's "Morning Preparation" scenario: needs an overview before leaving home.
FR-02	**Scene Activation**	The user shall be able to activate predefined scenes and modes (e.g., *Leave Home*, *Night*) with a few taps.	Giulia and Marco's scenarios emphasize quick scene activation.
FR-03	**Device Control**	The user shall control individual devices (on/off, brightness, temperature) from the relevant room view.	Marco's "Evening Comfort" scenario: direct device control.
FR-04	**Scheduling**	The system shall allow creation, modification, and deletion of schedules for lights, or heating.	Marco's "Creation of Schedule" scenario: easy time-based configuration.
FR-05	**Analytics Visualization**	The user shall access graphical representations of energy consumption over time (daily, weekly, monthly).	Giulia's interest in monitoring efficiency.

FR-06	**Scene and Routine Management**	Users shall create new automation routines by combining multiple device actions and triggers.	General need for flexible home management.
FR-07	**User Feedback and Confirmation**	The app shall provide visible feedback (color change, toasts, messages) confirming completed actions.	Both personas value reassurance after actions.

Table 3.1: Functional Requirements

3.6.2 Non-Functional Requirements

Non-functional requirements define *how* the Smartotum app should behave, ensuring that its usability, performance, and design quality support an optimal user experience.

ID	Requirement	Description	Design Principle Link
NFR-01	**Usability**	The interface must be intuitive and require minimal learning effort for first-time users.	Simplicity and cognitive ease.
NFR-02	**Consistency**	The visual and interaction logic must be uniform across all sections of the app.	Consistency and predictability.
NFR-03	**Feedback Responsiveness**	The system must display a confirmation or visual change within 1 second after any user action.	Feedback and system transparency.

NFR-04	**Accessibility**	Texts, colors, and components must comply with WCAG 2.1 AA standards for contrast and readability.	Accessibility and inclusiveness.
NFR-05	**Performance**	Core functions (scene activation, device updates) must respond within 2 seconds on standard mobile hardware.	Reliability and user trust.
NFR-06	**Visual Coherence**	The UI must maintain consistent spacing, typography, and iconography as defined in the Smartotum design system.	Aesthetic coherence and brand alignment.
NFR-07	**Scalability**	The system must support integration of new devices and sensors without redesigning the interface.	Flexibility and future growth.
NFR-08	**Security and Privacy**	User credentials and home data must be securely stored and transmitted.	Trustworthin ess and system transparency.

Table 3.2: Non-Functional Requirements

Chapter 4

Ideate – Concept and Wireframes

4.1 Introduction to the Ideate Phase

The Ideate phase represents the third stage of the Design Thinking process and follows directly from the Define phase. This stage encourages designers to explore a broad range of creative possibilities before converging on feasible and user-centred solutions [23]. It is the moment when analytical insights are transformed into design opportunities, allowing ideas to evolve from abstract definitions into concrete forms.

In this research, the Ideate phase translates the outcomes of the previous chapter—user insights, personas, scenarios, and requirements—into structured design directions. The process focuses on conceptual development, information architecture, user flows, and low-fidelity wireframes that define how the Smartotum application can deliver clarity, reliability, and simplicity in daily use. Visualizing early design structures helps bridge abstract goals with tangible interaction logic, enabling designers to test hierarchy and usability before committing to aesthetic details [24].

The aim of this phase is therefore to transform defined principles into coherent interface concepts that will guide the creation of the high-fidelity prototype in the next stage of the process.

4.2 Concept Development

The concept development phase translated the analytical findings from the *Define* stage into a structured design direction for the Smartotum application. This phase aimed to identify the key user needs and usability challenges to be addressed in the redesign and to transform them into coherent interface concepts.

Rather than focusing on visual style, this stage concentrated on defining the functional and interaction logic that would later inform the low-fidelity wireframes and prototype.

4.2.1 Method

The ideation process followed a structured yet creative approach grounded in the principles of Design Thinking. Insights gathered during the *Empathize* and *Define* phases—particularly from the user personas, user scenarios, and benchmarking—were synthesized through an **affinity mapping** session. This method was chosen because it allows identifying recurring patterns and relationships among user needs, pain points, and interface problems, therefore revealing key design opportunities in a user-centred way.

The mapping was conducted digitally using grouped sticky notes to visualize the hierarchy of ideas and overlapping goals. Each note represented an insight or requirement derived from previous research phases, such as the need for simpler navigation, clearer system feedback, or improved automation control. By organizing these ideas into clusters, the process facilitated the definition of five conceptual themes that would shape the Smartotum redesign.

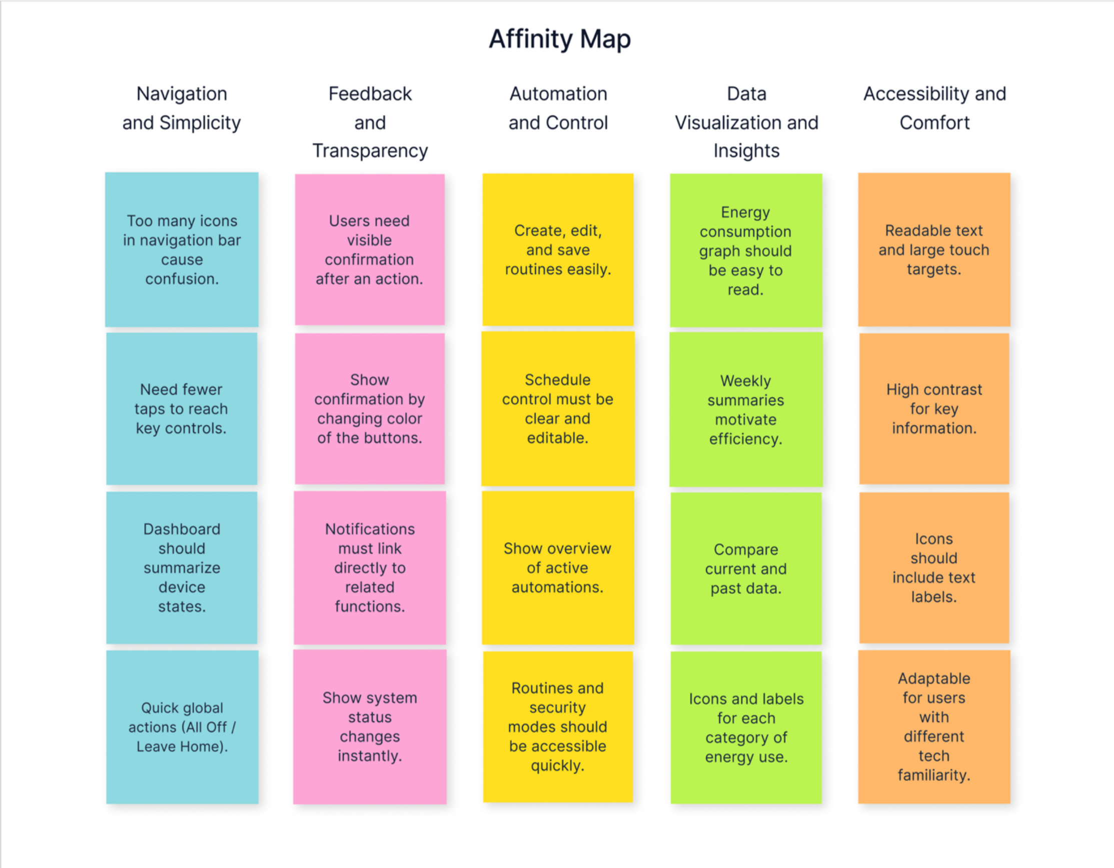

Figure 4.1: Affinity Map: Clustering of Insights from the Empathize and Define Phases.

The figure summarizes the thematic organization of user insights into five categories: Navigation and Simplicity, Feedback and Transparency, Automation and Control, Data Visualization and Insights, and Accessibility and Comfort. Each category represents a set of design priorities derived from the user personas, scenarios, and benchmark analysis.

4.2.2 Concept Themes

The affinity mapping process revealed five major themes that guided the conceptual direction of the Smartotum interface:

- **Navigation and Simplicity** – Users expressed a need for quick access to essential functions with minimal cognitive effort. Simplifying the navigation structure, reducing the number of icons, and integrating a global dashboard for key actions were identified as priorities.

- **Feedback and Transparency** – Clear visibility of system status and confirmation of actions were recognized as essential for building user trust. Every control should provide immediate visual or textual feedback, such as color changes or confirmation messages.
- **Automation and Control** – Users value flexibility in creating and modifying automations. The interface must make it easy to create routines and schedules while clearly displaying their active or inactive state.
- **Data Visualization and Insights** – Information about energy consumption and system activity should be presented in a clear, visually organized manner. Graphs and summaries must help users understand patterns and track efficiency over time.
- **Accessibility and Comfort** – The interface must be inclusive and usable for users with different levels of technical familiarity. Legible typography, sufficient contrast, and clear labeling enhance readability and comfort in daily use.

These themes collectively shaped the conceptual model of the Smartotum redesign.
The next stage, presented in Section 4.3, translates these conceptual themes into low-fidelity wireframes that define layout hierarchy, navigation flow, and interaction patterns.

4.3 Information Architecture

Defining the information architecture (IA) was an essential step in translating conceptual ideas into a structured and navigable digital environment. The IA defines how information is organized, categorized, and connected within the Smartotum application, ensuring that users can intuitively locate and manage smart-home functions.

Building upon the insights synthesized in the Affinity Map (Figure 4.1), the IA was developed to reflect key design priorities identified in the Define phase — including clarity, accessibility, and minimal navigation depth. Each screen and navigation path was mapped to support a seamless flow between primary and secondary interactions.

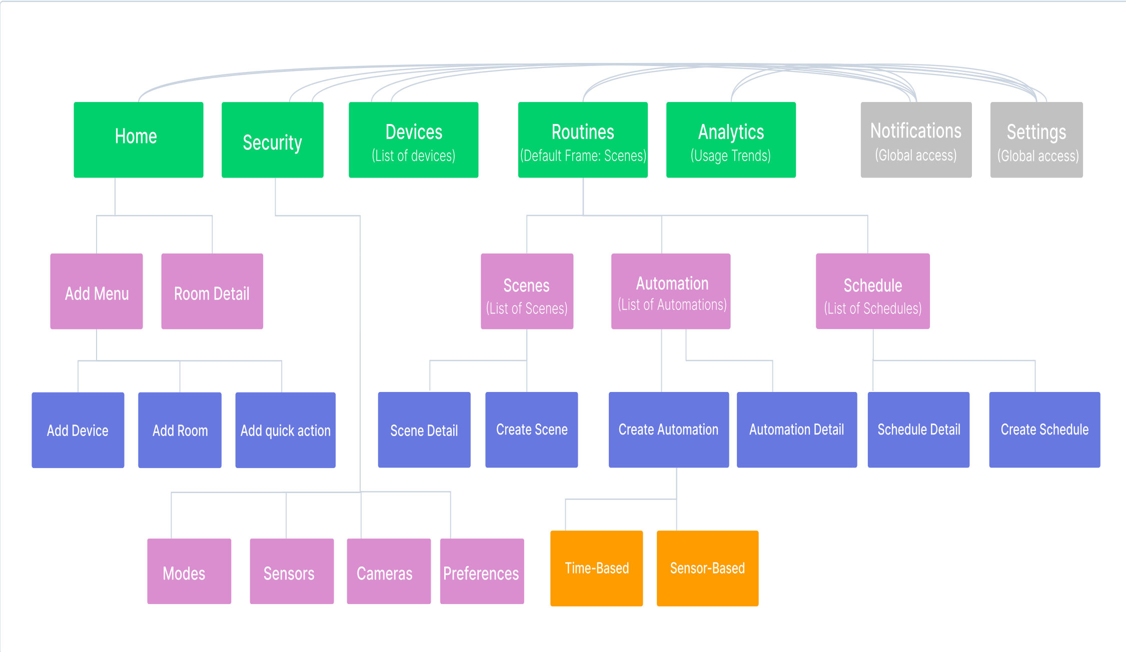

Figure 4.2: Site Map of Smartotum Application

The site map outlines four main sections accessible via the bottom navigation bar: **Home, Devices, Routines, and Analytics.** These represent the primary functional areas of the application. Additionally, **Notifications** and **Settings** are designed as global components, accessible from the top bar on every screen. This ensures that users can quickly view system alerts or adjust settings without interrupting their current task flow.

- The **Home** screen functions as the central dashboard, providing access to essential device summaries, Climate, security mode, quick actions, room overviews, favorite devices, and scenes.
- The **Devices** section lists all connected devices and their categories (such as lights, plugs, and climate), with configuration and control.

- The **Routines** section is divided into three subsections—Scenes, Automation, and Schedule—allowing users to create personalized automations or scheduled actions.
- The **Analytics** section visualizes energy consumption trends, providing feedback that supports energy efficiency.
- The **Notifications** and **Settings** elements maintain consistent placement in the top interface area, offering immediate access to alerts and system preferences across all main sections.

This hierarchical structure ensures that all key functions are reachable within one or two interactions from the main navigation.

The defined information architecture provided a clear foundation for the visual structuring of the interface. Based on this hierarchy, the next stage focused on transforming the mapped screens and navigation logic into tangible layouts through low-fidelity wireframes. These wireframes served as early visual representations of content organization, interaction patterns, and functional grouping, allowing for quick iteration and validation before moving toward high-fidelity prototyping.

4.4 User Flows

To translate the information architecture into actionable interaction logic, four key user flows were developed to model how the two personas (Giulia and Marco) accomplish essential tasks within the Smartotum system. User flows were selected based on the scenarios defined in Chapter 3 and represent typical, high-frequency interactions involving scene activation, security monitoring, environmental control, and schedule configuration.
These flows establish the behavioral foundation for the subsequent low-fidelity wireframes and high-fidelity prototype.

4.4.1 Flow 1 — Activating the “Leave Home” Scene

This flow models Giulia’s routine action before leaving home, showing two alternative entry points: a **direct path** from the Home dashboard and an **indirect path** through the Routines section. In both cases, the user initiates the scene by tapping its card, after which the system applies the predefined settings and provides immediate confirmation through a visual state change of the scene button. The dual-path design supports both efficiency-oriented behavior (quick activation from Home) and structure-oriented behavior (activation from Routines). This flow ensures that scene activation remains fast, intuitive, and consistent across screens.

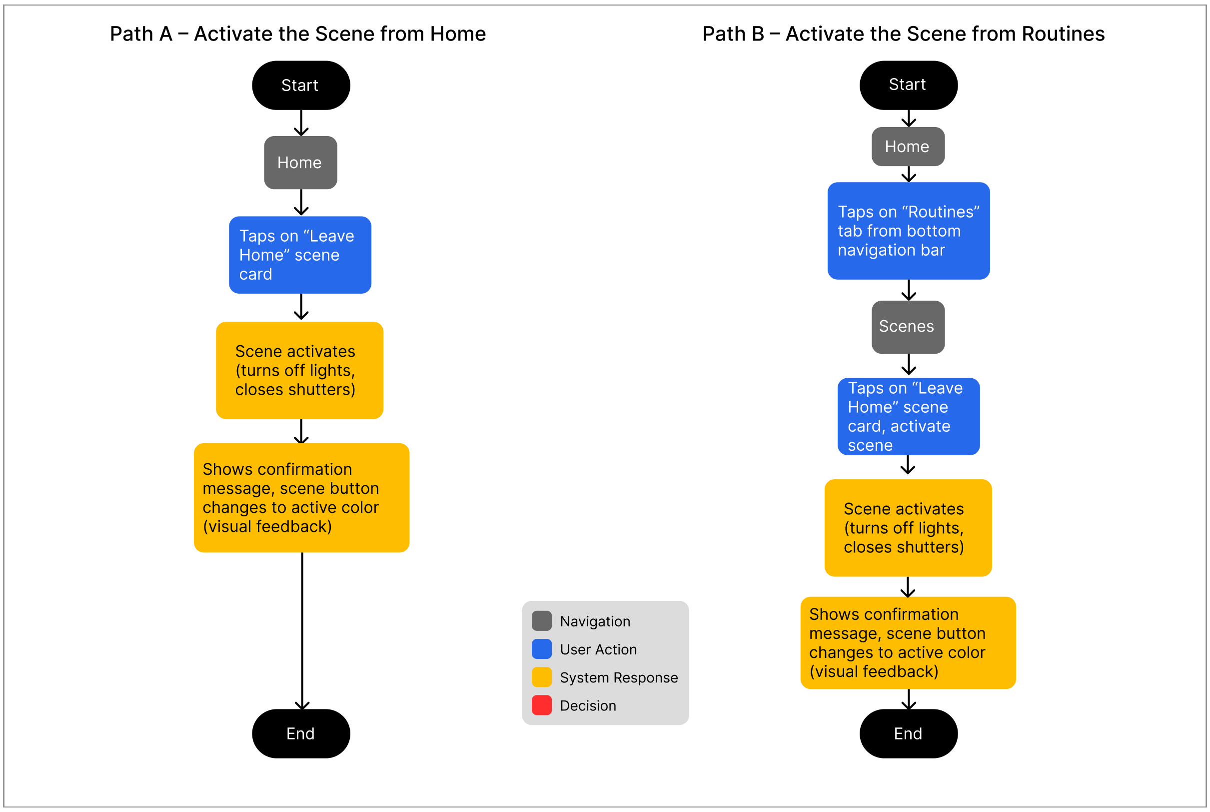

Figure 4.3: User Flow for Activating the “Leave Home” Scene.

4.4.2 Flow 2 — Activating the “Night” Security Mode

This flow models Marco’s routine of preparing his home for the night by activating a previously configured security mode. The sequence begins on the

Home screen, where the user navigates to the Security section of the application. Once on the Security screen, Marco selects the "Night" mode, which he uses to secure doors, windows, and motion sensors before going to bed. Upon tapping the mode, the system instantly applies the predefined security settings and updates the interface through two forms of feedback: (1) the mode button changes color to indicate its active state, and (2) the status text updates to "Armed – Night." This combination of visual and textual confirmation reassures the user that the system is correctly armed and functioning as expected.

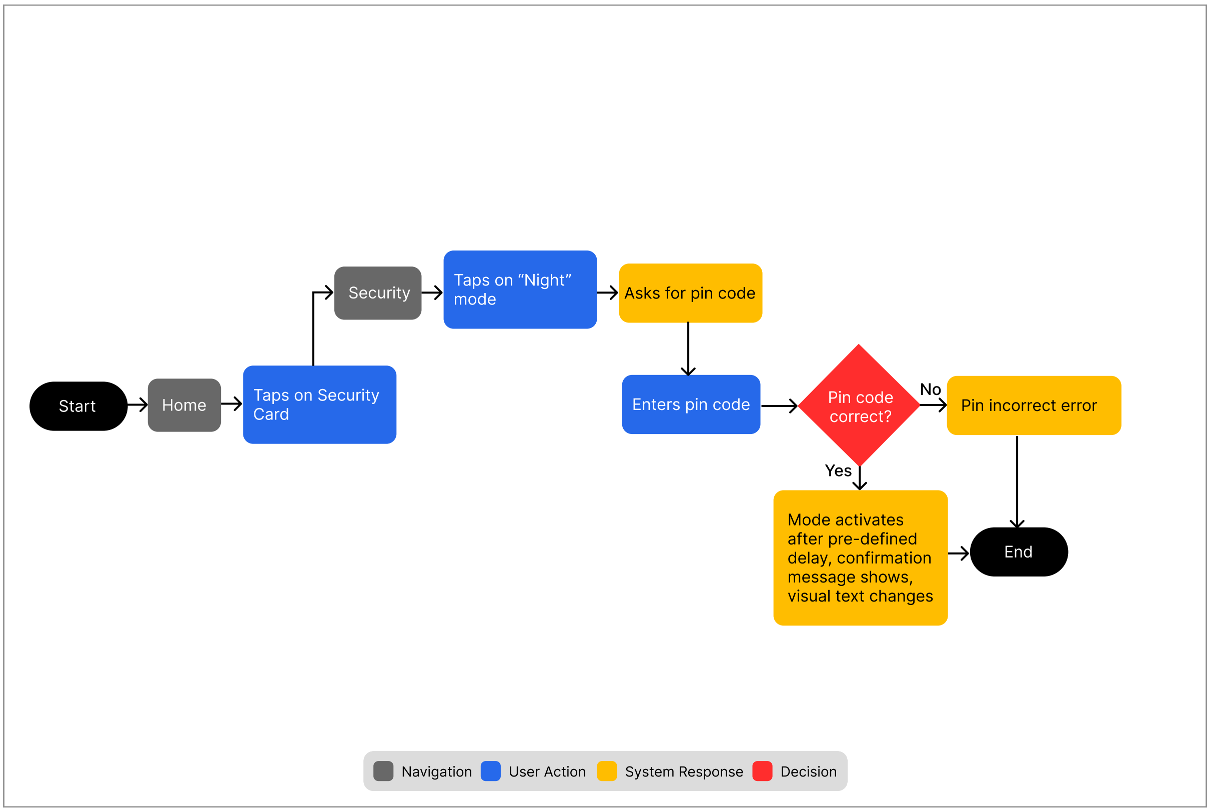

Figure 4.4: User Flow for Activating the "Night" Security Mode.

4.4.3 Flow 3 — Adjusting Lights and Temperature

This flow illustrates Marco's evening interaction with the Devices section to adjust lighting and climate settings. After navigating to the Devices screen, the user toggles a light, adjusts brightness, and modifies the air-conditioning mode and temperature. Each user action is followed by an immediate system response, visible through updated values and color-state changes.

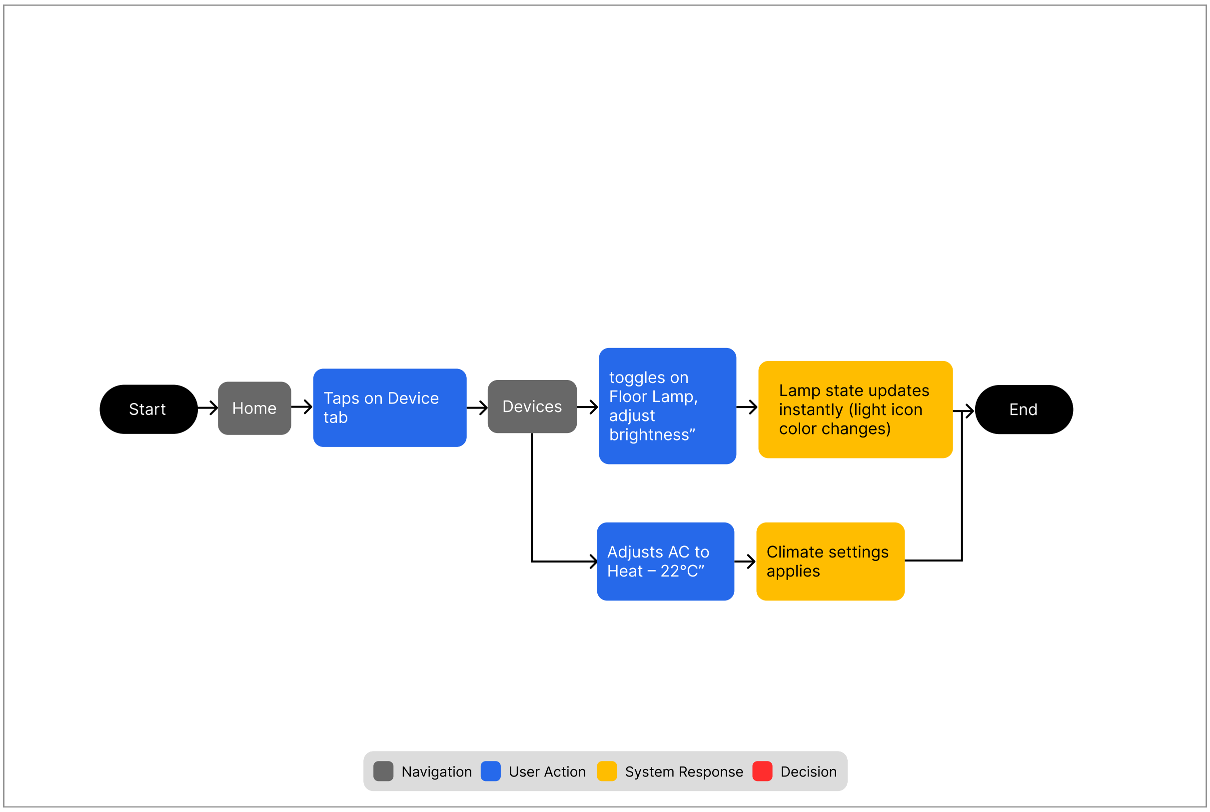

Figure 4.5: User Flow for Adjusting Lighting and Temperature.

4.4.4 Flow 4 — Creating a New Heating Schedule

This flow models Marco's weekend task of configuring a new schedule. After accessing the Routines section and selecting the Schedules view, the user taps "Add Schedule," which navigates to a dedicated schedule-creation screen. The user enters the required parameters (devices, times, days, temperature mode), after which a decision node verifies whether all mandatory fields are completed. If so, the schedule is saved and confirmed.

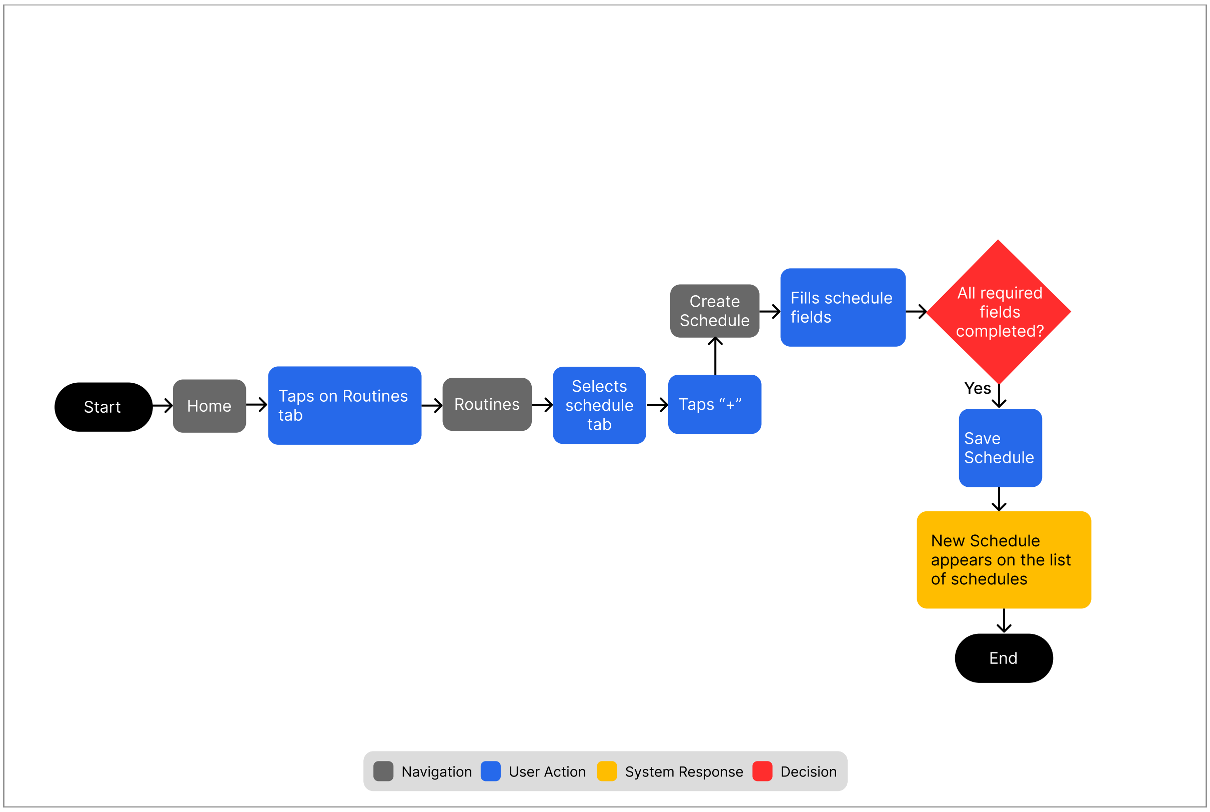

Figure 4.6: User Flow for Creating a New Schedule.

These four flows formalize the functional logic of Smartotum and serve as a blueprint for the design of the low-fidelity wireframes. They clarify the required screens, navigation patterns, decision points, and system feedback mechanisms.

4.5 Low-Fidelity Wireframes

Following the definition of the information architecture, low-fidelity (lo-fi) wireframes were developed to translate the conceptual structure into visual form. The goal of this stage was to explore layout composition, navigation flow, and content hierarchy without focusing yet on visual styling or graphical refinement.

The wireframes were created digitally, ensuring consistent alignment with the defined site map and allowing for quick iteration and adjustment. Each screen was designed to represent a key section of the application—**Home, Devices,**

Routines, Analytics, Notifications, and Settings—reflecting the functional priorities identified during the Define phase.

At this stage, visual elements such as icons, colors, and typography were intentionally simplified, allowing attention to remain on usability and information flow. The layouts were structured using grid-based organization, consistent spacing, and intuitive grouping of related components to support clarity and predictability.

The **Home** screen concept focused on summarizing essential device information and providing quick actions such as activating modes or scenes. The **Devices** section was organized by category (e.g., lights, climate, smart plugs), offering a clear list with toggle-based interactions for instant control. The **Routines** screen explored three distinct tabs—**Scenes**, **Automation**, and **Schedule**—to separate different levels of customization while maintaining a unified navigation pattern. The **Analytics** wireframe introduced early concepts of visual summaries and energy insights.

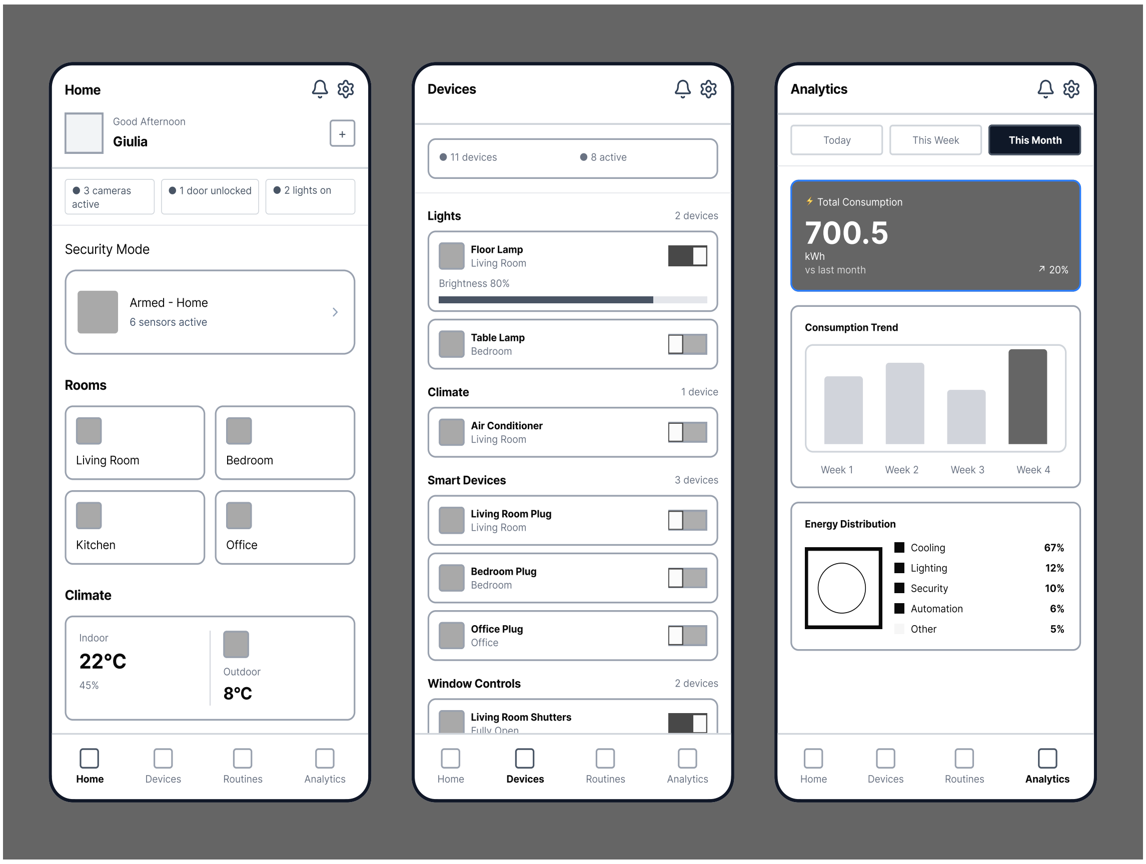

Figure 4.7.1: Low-Fidelity Wireframes of Smartotum Application – Home, Device, and Analytics frame

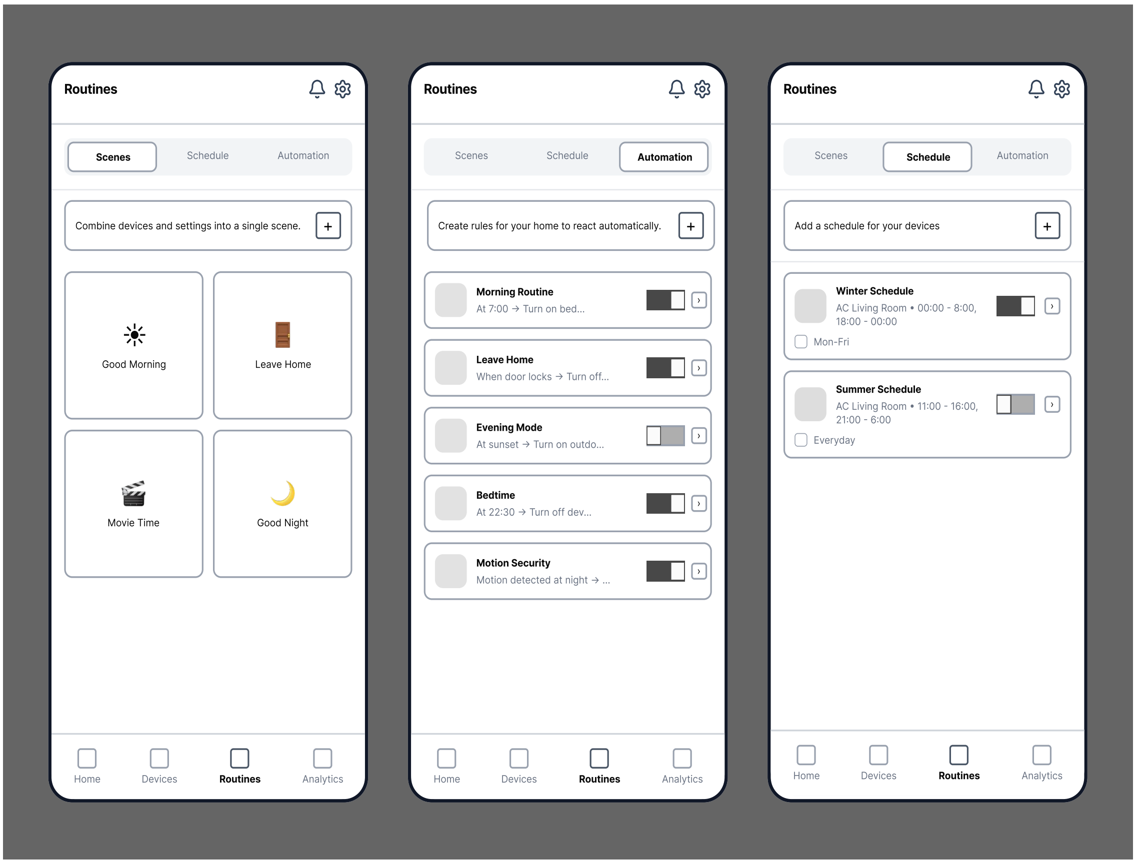

Figure 4.7.2: Low-Fidelity Wireframes of Smartotum Application – Routines frame

The low-fidelity wireframes illustrate the structural layout and functional organization of the main sections of the Smartotum application. Figure 4.3.1 presents the **Home**, **Devices**, and **Analytics** screens, which establish the visual hierarchy and the placement of essential interactive elements. The Home screen functions as the primary dashboard, having add button for adding devices, rooms, and quick actions, while summarizing security status, available rooms, and climate. Also, by scrolling the frame, quick actions, favorite devices, and scenes can be seen for a fast adjustment. The Devices section lists controllable devices grouped by type, providing toggle-based interaction for immediate feedback. The Analytics screen introduces a clear, card-based structure that displays energy consumption and usage trends. Moreover,

Notifications and **Settings** icons are available in every frame for quick access to their respective frames.

Figure 4.3.2 focuses on the **Routines** section, including *Scenes*, *Automation*, and *Schedule*. These layouts explore alternative ways of managing everyday actions, such as activating predefined scenes, defining automatic responses, or setting timed routines. The uniform placement of navigation elements and the consistent visual rhythm across all wireframes ensure ease of recognition and predictable interaction.

The wireframing process enabled the validation of layout decisions before the integration of detailed UI elements. Feedback gathered during this stage informed subsequent refinements to navigation hierarchy and the grouping of interactive components.

4.6 Iterations and Refinements

The transition from low-fidelity wireframes to the high-fidelity prototype involved several rounds of structural and visual refinements. These refinements were guided by the conceptual themes defined earlier (clarity, simplicity, consistency, and quick access to key actions), as well as the insights derived from the user flows and scenarios. While the low-fidelity wireframes provided an initial functional structure, the iterative process focused on improving hierarchy, reducing cognitive load, and ensuring coherent navigation across the application.

Reorganization of the Home Screen

One of the refinements occurred on the Home screen. In the early version, the placement of cards followed a basic functional grouping, but their order did not clearly reflect actual usage priorities. Based on the user scenarios and design principles of efficiency and clarity, the hierarchy was reorganized. The new layout places **Security Modes** at the top of the screen, as they represent high-priority, safety-related actions. Immediately below them, **Quick Actions** were moved upward to enable fast access to frequently used controls.

Climate information and controls, previously placed higher in the early version, were relocated beneath Quick Actions, acknowledging that they are often secondary in urgency compared to immediate system controls. This reordering reinforces a more intuitive visual hierarchy, supports rapid task execution, and aligns the interface with real user priorities observed in the personas and scenarios.

Navigation Structure Update

Another key refinement involved the bottom navigation bar. In the early version, the navigation consisted of four primary sections: Home, Devices, Routines, and Analytics; however, usability analysis and scenario mapping revealed that security-related actions were frequent, high-priority tasks that required direct access. To address this, the navigation was expanded from **four** to **five** items, introducing a dedicated **Security** tab alongside **Home, Devices, Routines**, and **Analytics**. Adding Security as a top-level destination reduces navigation depth, supports faster access to critical information, and aligns the structure with the mental models of both personas—Giulia, who frequently monitors the home remotely, and Marco, who activates security modes as part of his nightly routine.

This modification improves clarity, increases predictability, and contributes to a more balanced and functional global navigation system.

Refinement of the Analytics Screen

The Analytics section also underwent significant refinement during the iterative process. In the low-fidelity wireframes, consumption data was presented in a simplified format with limited filtering options, relying on generic text labels such as “This Day,” “This Week,” and “This Month.” This approach did not provide sufficient flexibility for users who wished to explore consumption patterns more precisely. For the refinement, the Analytics screen was redesigned to integrate data coming directly from **energy sensors** that user had set before, offering a more comprehensive view of real-time and historical energy usage. Additionally, the method for selecting dates was improved through the introduction of a **calendar icon**, enabling more intuitive and flexible date selection.

These enhancements support Giulia's need for detailed monitoring and make the exploration of energy data more accessible, efficient, and visually coherent.

Improved Discoverability Through Chevron Indicators

Another transition was that chevron indicators were added across the interface to enhance clarity and guide user expectations about navigable elements. In the first version, several list items and cards lacked explicit affordances, which made it less clear whether tapping them would reveal additional details or configuration options. Chevrons were introduced wherever deeper information or secondary screens are available—for example, within the **Scenes** page, each scene now includes a chevron to indicate that further settings or device associations can be accessed. This refinement improves discoverability, reduces ambiguity, and aligns the interface with standard mobile interaction patterns, ensuring that users understand where additional content is located and how to reach it without unnecessary trial-and-error.

Unification of Iconography and Visual Consistency

A further refinement addressed the inconsistency of the icons. In the initial version, icons were sourced from mixed sets, leading to visual disparity across screens and reducing overall coherence. In the high-fidelity prototype, all icons were standardized using the **Lucide icon set**, which became the primary visual language throughout the interface [25]. This change was especially significant on the **Scenes** screen, where the previous icons were replaced with cleaner, more expressive Lucide icons that better aligned with the app's general visual identity. The unification of iconography strengthened consistency, improved recognizability, and contributed to a more polished and professional interface.

Chapter 5

Prototype – Interface Development

5.1 Introduction to the Prototype Phase

The Prototype phase represents the fourth stage of the Design Thinking process and marks the transition from conceptual exploration to concrete interface realization. While the Ideate phase established the structural foundation of the Smartotum application through information architecture, user flows, and low-fidelity wireframes, this phase focuses on transforming those abstract structures into a functional and visually coherent high-fidelity interface.

The objective of the Prototype phase is to develop a complete visual and interaction system that embodies the design principles defined in earlier chapters—clarity, simplicity, consistency, and rapid access to high-priority actions. Using Figma as the primary tool, the interface was refined through iterative visual decisions involving typography, color, iconography, spacing, and component behavior. The resulting high-fidelity prototype provides a realistic representation of the final user experience and serves as the basis for usability testing in the subsequent chapter.

5.2 Visual Design System

The visual design system defines the aesthetic and functional foundation of the Smartotum interface. It ensures consistency across screens, supports usability, and reinforces the brand identity. The high-fidelity prototype was developed using a modular approach—establishing reusable components, common visual patterns, and a coherent graphic language that improves clarity and reduces cognitive load for users. This section presents the key elements of the visual system, including the color palette, typography, iconography, spacing rules, and core UI components.

5.2.1 Color Palette

The color palette was designed to balance clarity, accessibility, and brand coherence. The interface uses a light background to support readability and create a sense of visual openness. Accent colors highlight interactive elements and provide immediate feedback on system status.

Primary Colors

- **Blue**: `#155DFC` - Active navigation items.
- **Blue**: `#1877F2` - Button Colors

Background Colors

- **Primary Background:** Linear `#F8FAFC` to `#F1F5F9` (light gray)
- **Card Background:** `#FFFFFF` (white)
- **Icon Backgrounds:** Soft pastels - `#FEF3C6` (yellow), `#DBEAFE` (blue), `#DCFCE7` (green), `#FE9A00` (orange), `#E8CFAC` (brown), `#F1F5F9` (grey) (off state).

Text Colors:

- **Primary Text:** `#0A0A0A` and `#0F172B` (dark gray/dark navy)
- **Secondary Text:** `#62748E` (medium gray)

The palette maintains consistency across screens and ensures that status changes (lights on/off, active/inactive modes, warnings) are immediately noticeable.

5.2.2 Typography

Inter, an open-source sans-serif typeface, is used across the application to maintain consistency and minimize visual noise.

Font Sizes:

- **Page Titles:** 16px ("Home", "Living Room", "Devices")
- **Section Headers:** 16px ("Security Mode", "Quick Actions", "Lights")
- **Card Titles:** 16px ("Floor Lamp", "Armed - Home")
- **Body Text:** 12-14px ("6 sensors active", "Corner light")
- **Small Text:** 10-12px ("Indoor", nav labels)

The typography system reinforces clarity, ensuring that users can quickly scan and interpret information.

5.2.3 Iconography

The iconography in the high-fidelity prototype is based on the **Lucide icon set**, an open-source library licensed under the **ISC License** [25].

Icons are used to:

- Support quick recognition of navigation items (Home, Devices, Security, Routines, Analytics).
- Represent device types (lights, climate, shutters, sensors).
- Indicate interactive elements or menus (chevrons, toggles, edit icons).
- Provide visual cues in scenes and action cards.

To maintain consistency, icons follow:

- A uniform stroke width

- A rounded, minimalistic aesthetic
- Consistent sizing within the grid system

This creates a predictable and intuitive visual experience.

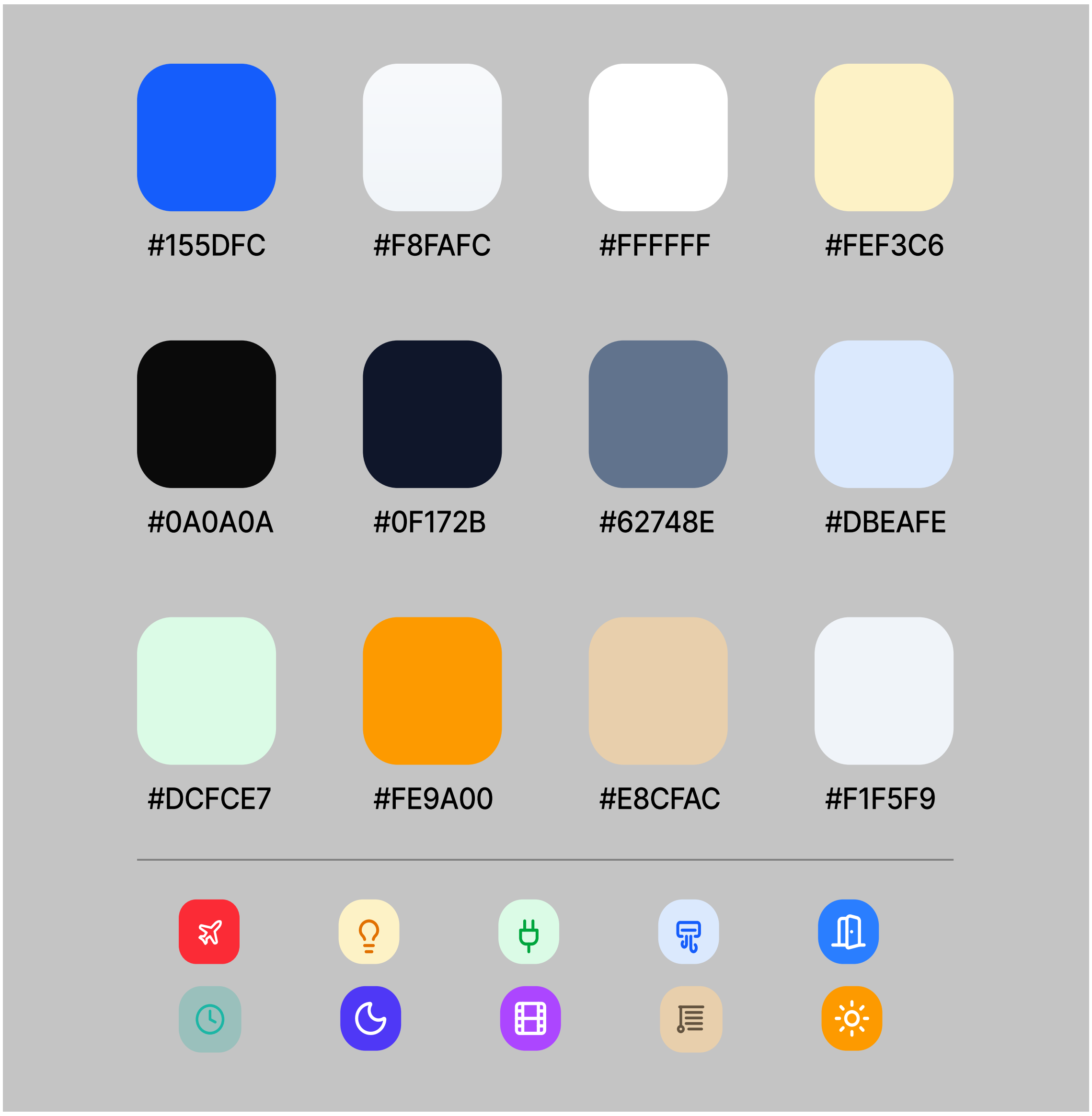

Figure 5.1: Color Palette and Icons

5.2.4 Layout and Spacing

The layout uses a structured grid system achieved by auto-layout in Figma, with consistent spacing between elements to ensure readability, visual balance, and alignment. Key principles include:

- **Uniform padding** inside cards and containers
- **Consistent vertical spacing** between modules to create clear separation
- **Rounded card corners** to match the overall modern aesthetic
- **A responsive, column-based grid** ensuring scalability for future multi-device applications

Spacing follows multiples of **4 or 8 pixels**, a standard practice in modern mobile UI design that maintains visual rhythm and harmony across screens.

5.2.5 Core Components

A set of reusable components was designed in Figma to ensure consistency and support rapid prototyping:

Cards
Used for modules such as Scenes, Rooms, Security Modes, and Quick Actions. Each card includes a title, icon, and optional status indicator.

Buttons
Primary buttons use the brand blue color and are reserved for key actions. Secondary buttons follow the pastel palette colors based on the functionality of the buttons.

Toggles and Switches

Used for device states (lights on/off, heating modes), styled with clear color feedback to indicate active/inactive states.

Chevrons
Added to all list items that lead to deeper information, improving discoverability.

Status Indicators
Color-based or icon-based cues that reflect real-time system state (e.g., shutters closed, alarm active, light level).

These components form a cohesive design language that improves usability and ensures predictable behavior across the application.

5.3 High-Fidelity Prototype Overview

The high-fidelity prototype represents the visual and interactive realization of the Smartotum interface, translating the structural decisions from the Ideate phase into a functional, polished design. While the low-fidelity wireframes established the core layout, information architecture, and user flows, the high-fidelity prototype introduces the final visual language, component specifications, and interaction behaviors defined by the design system. Created in Figma, the prototype reflects the complete set of design principles outlined earlier—clarity, simplicity, consistency, and rapid access to priority actions.

The prototype includes fully designed screens for all primary sections of the application (Home, Devices, Security, Routines, Analytics), along with secondary screens such as room details, schedules, and scenes. Each screen integrates the finalized color palette, the standardized Lucide iconography, and the spacing and layout guidelines described in the design system. Interactive components such as cards, toggles, status indicators, and chevrons are implemented consistently across the interface to reinforce predictability and reduce cognitive load.

Beyond visual refinement, the high-fidelity prototype incorporates interaction logic that mirrors the intended user experience. The following sections present the key screens of the prototype and highlight the interaction patterns that define the final interface.

5.4 Key Screens and Interactions

This section presents the primary screens of the Smartotum high-fidelity prototype and explains the structure, functionality, and interaction logic of each one. The screens illustrate how the visual design system, interaction patterns, and navigation structure come together to create a coherent and intuitive user experience. Each screen has been designed to support the needs of the identified personas—Giulia and Marco—by enabling rapid access to essential actions, providing clear system feedback, and maintaining a consistent visual hierarchy throughout the app.

5.4.1 Home Screen

The Home screen serves as the main control hub of the Smartotum application and offers an overview of the system's most important states and quick-access actions. It is organized into vertical modules that reflect the redesigned hierarchy established during the Ideate phase. At the top, the **Security Mode** card displays the currently active mode (e.g., *Armed – Home*) along with a set of alternative modes that the user can activate with a single tap. Below this, the **Quick Actions** section provides immediate controls such as turning off all lights, activating Away Mode, or closing all shutters. These actions use distinct accent colors to visually differentiate their purpose and urgency. The lower modules include **Climate** and **Rooms** cards. Climate card presents concise information of the current temperature (indoor and outdoor), and by tapping, it navigates to AC device in the **Devices** tab for further adjustment of the temperature. The room cards, shows available rooms in the house. Selecting a room (e.g., *Living Room*) leads to a detailed room page, where devices are listed with individual control elements such as toggles, brightness sliders, and mode selectors. Device states are always communicated visually through color, icon changes, or labels such as "On," "Off," or percentage values.

The Home screen is designed to accommodate both quick, high-priority interactions and routine system checks, making it suitable for the everyday behavior of both personas.

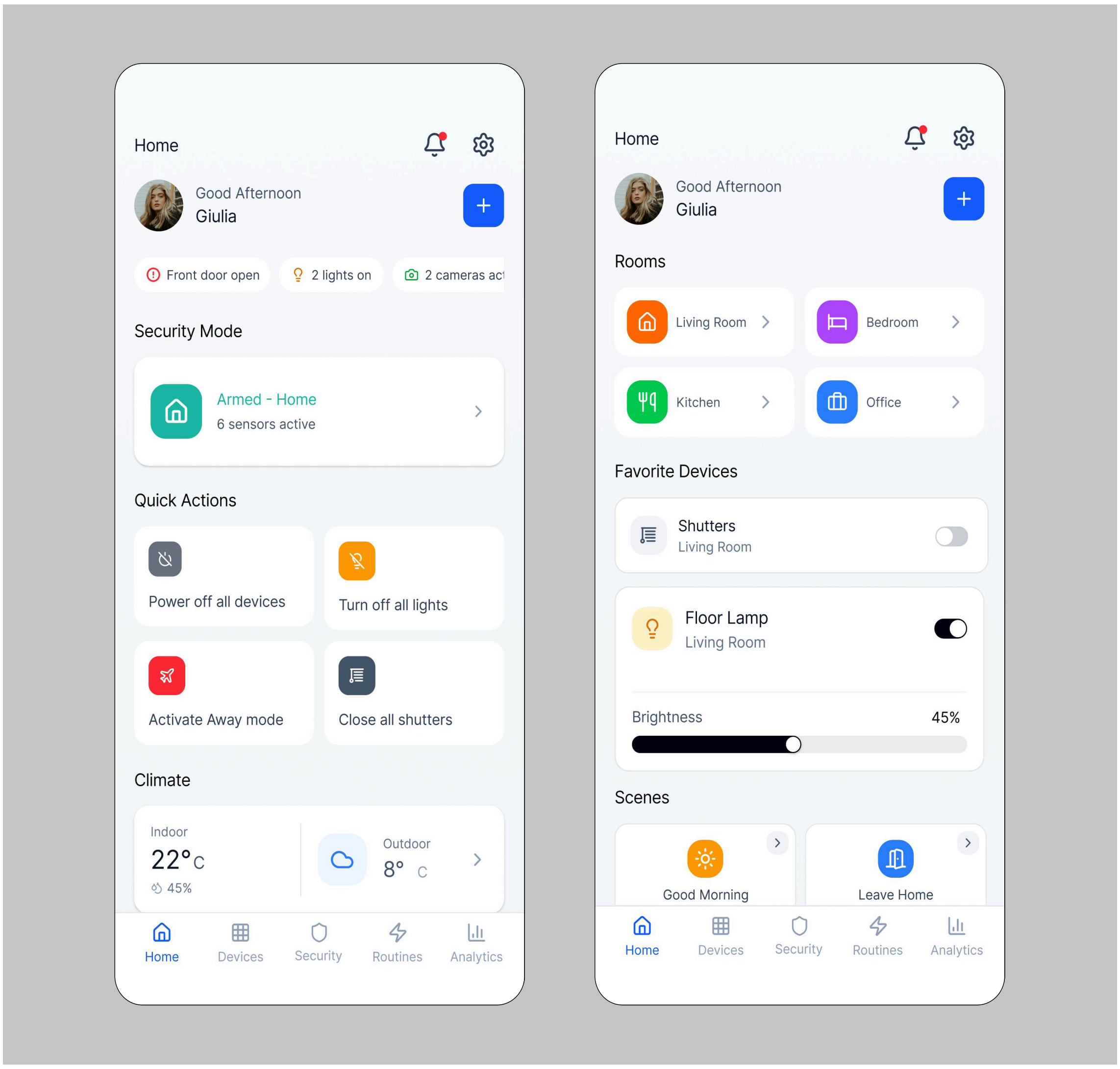

Figure 5.2.1: Home Screen

5.4.2 Devices Screen

The Devices screen provides an overview of all available devices, structured into clearly labeled cards. At the top of the screen, the number of total devices and the number of active devices are shown. Then, all devices organized by their category are displayed. Each device card has the control configuration for it, e.g., by toggling the Air Conditioner on, its operating mode (Heat, Cool, Fan) and temperature can be adjusted.

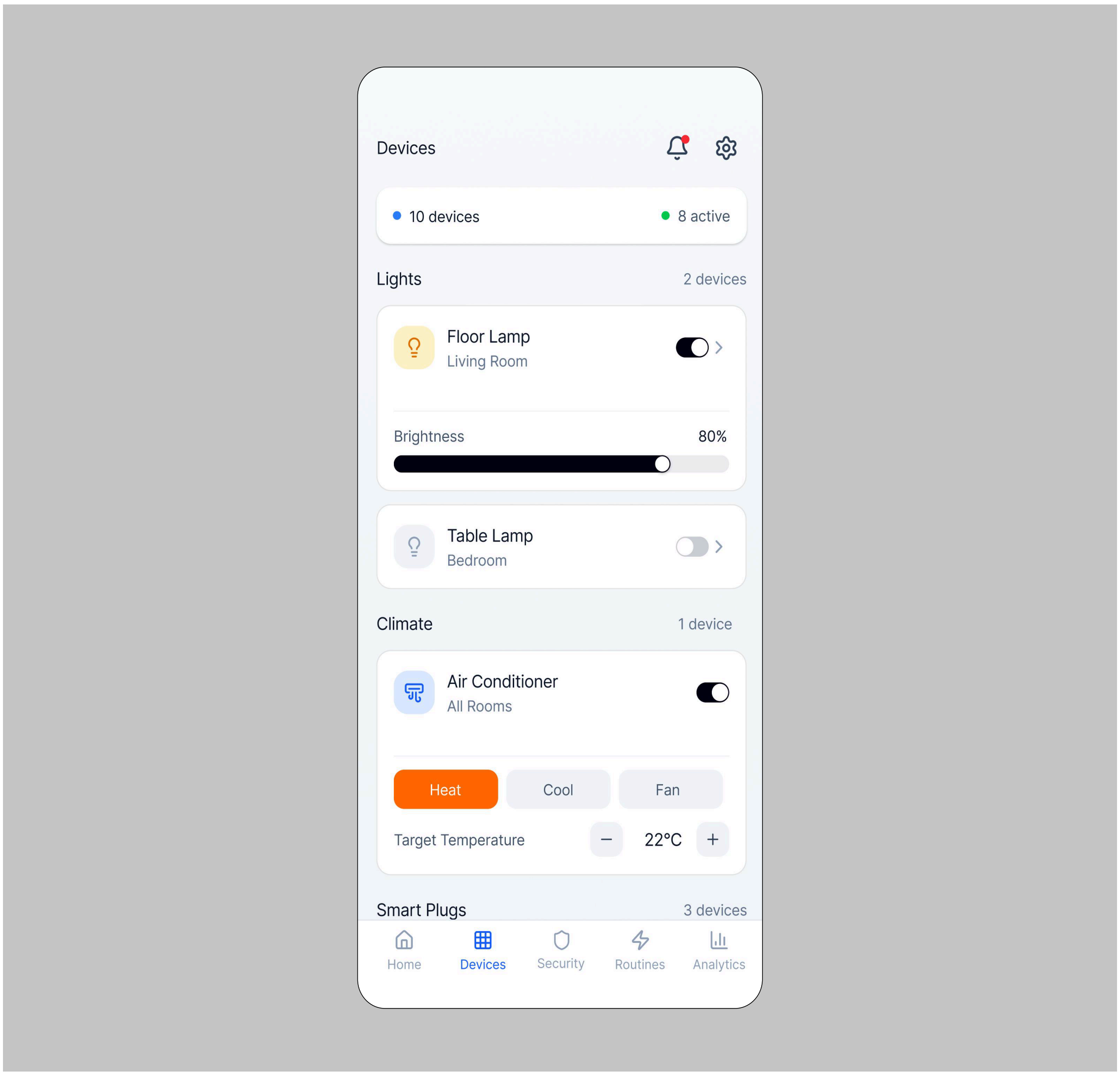

Figure 5.2.2: Devices Screen

5.4.3 Security Screen

The Security screen centralizes all safety-related components of the smart-home system. Modes, Sensors, Cameras, and Preferences are the four sub-screens of security, which can be reached through the toggle bar.

The primary element is the **Modes** module, allowing users to switch between created modes like Home, Night, or Away. Activating a mode results in an immediate state update—e.g., button color changes and text such as *Armed – Night*—providing reassurance and clear feedback. Modes can be created by tapping on the "+" button, which shows a bottom sheet screen for choosing a name for the mode and selecting related sensors. For each mode card, there are chevrons that, by tapping, display the active sensors related to that mode.

The second element is **Sensors**, which shows all of the available sensors and their status. Also, with the "+" button, new sensors can be added.

The third screen, which is **Cameras**, is for showing the footage of the cameras installed.

Ultimately, the last screen is **Preferences**, which shows Last Activity, Activation Delay, Users, and Emergency contact.

This layout reflects the needs of both personas: Giulia, who regularly checks the system remotely, and Marco, who uses security modes as part of his evening routine.

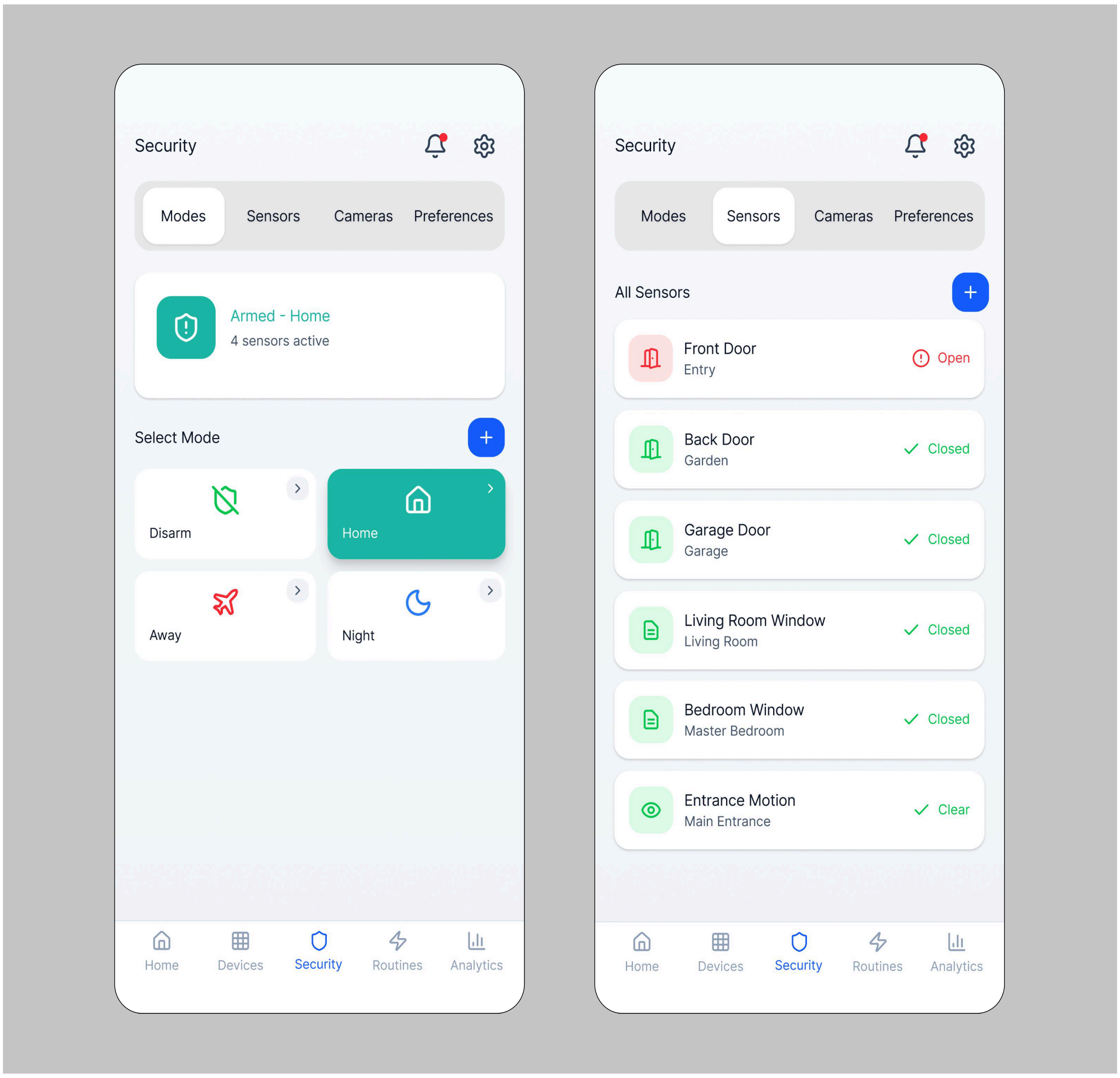

Figure 5.2.3.1: Security Screen — Modes, Sensors

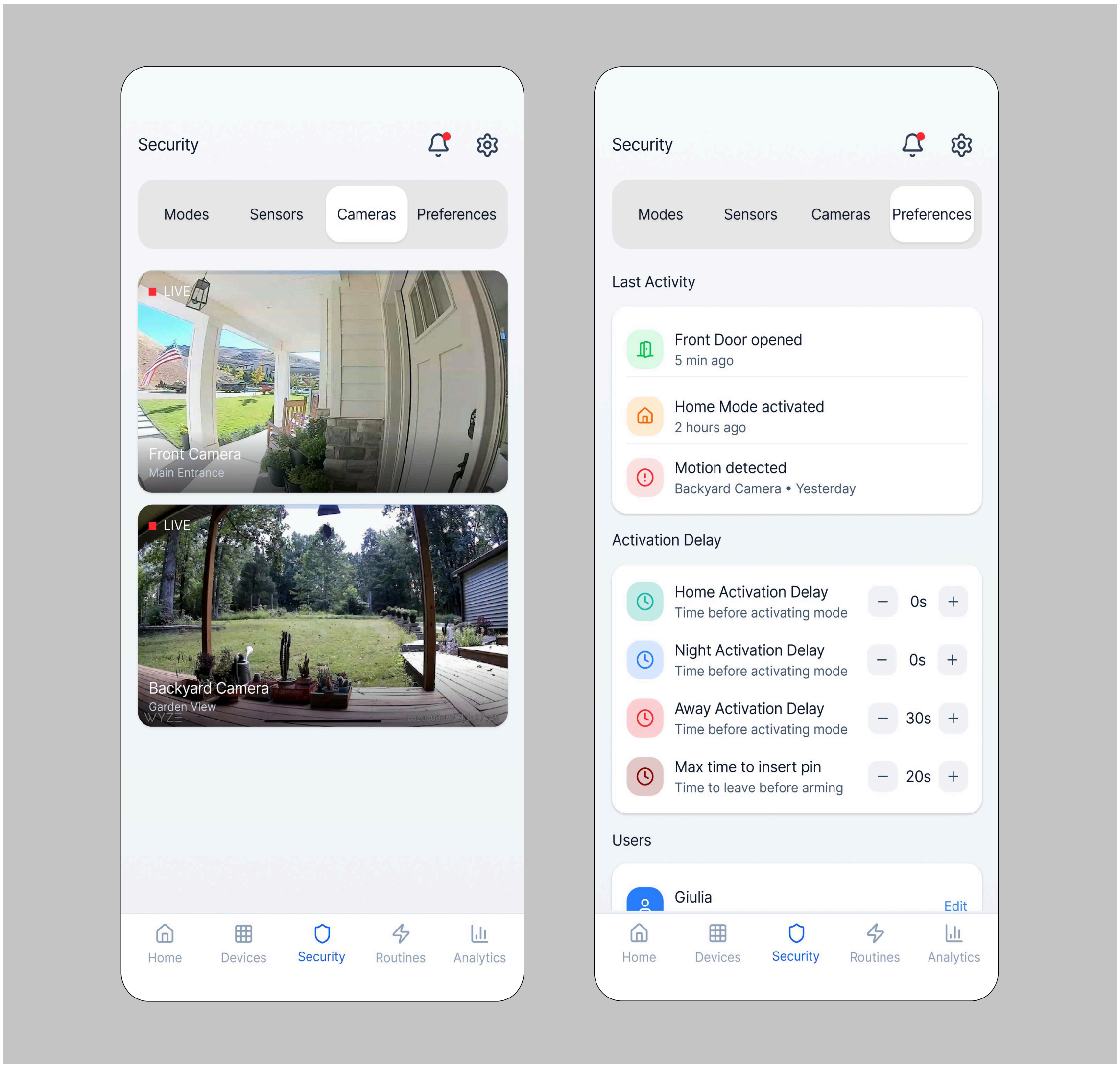

Figure 5.2.3.2: Security Screen — Cameras, Preferences

5.4.4 Routines Screen

The Routines screen allows users to automate frequently used configurations and actions. It has three toggle elements, named as **Scenes**, **Schedule**, and **Automation**.

Scenes are presented as large visual cards with identifiable icons (e.g., *Good Morning*), each accompanied by a chevron to indicate further details. Activating a scene updates the home environment instantly, while opening one reveals associated devices and triggers.

A schedule is used for routines that are based on time ranges. Such as configuring climate devices to be enabled in a certain time range and days (e.g., Winter Schedule).

Automation is a kind of routine that can be triggered by time or a sensor (e.g., when the door opens, turn on the table lamp).

For each element, there is an add ("+") button for new configurations, and a toggle for enabling or disabling them.

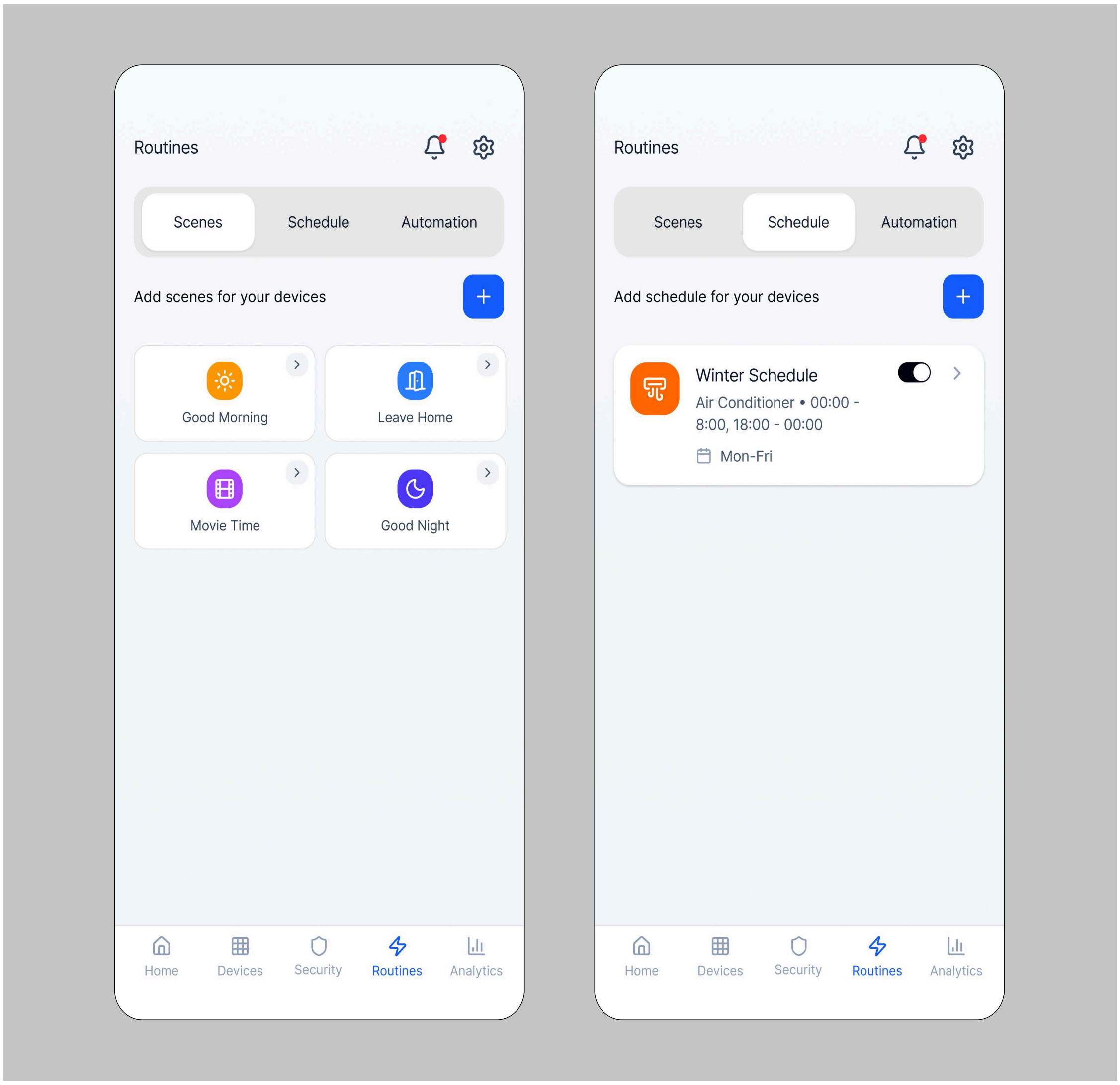

Figure 5.2.4.1: Routines Screen — Scenes, Schedule

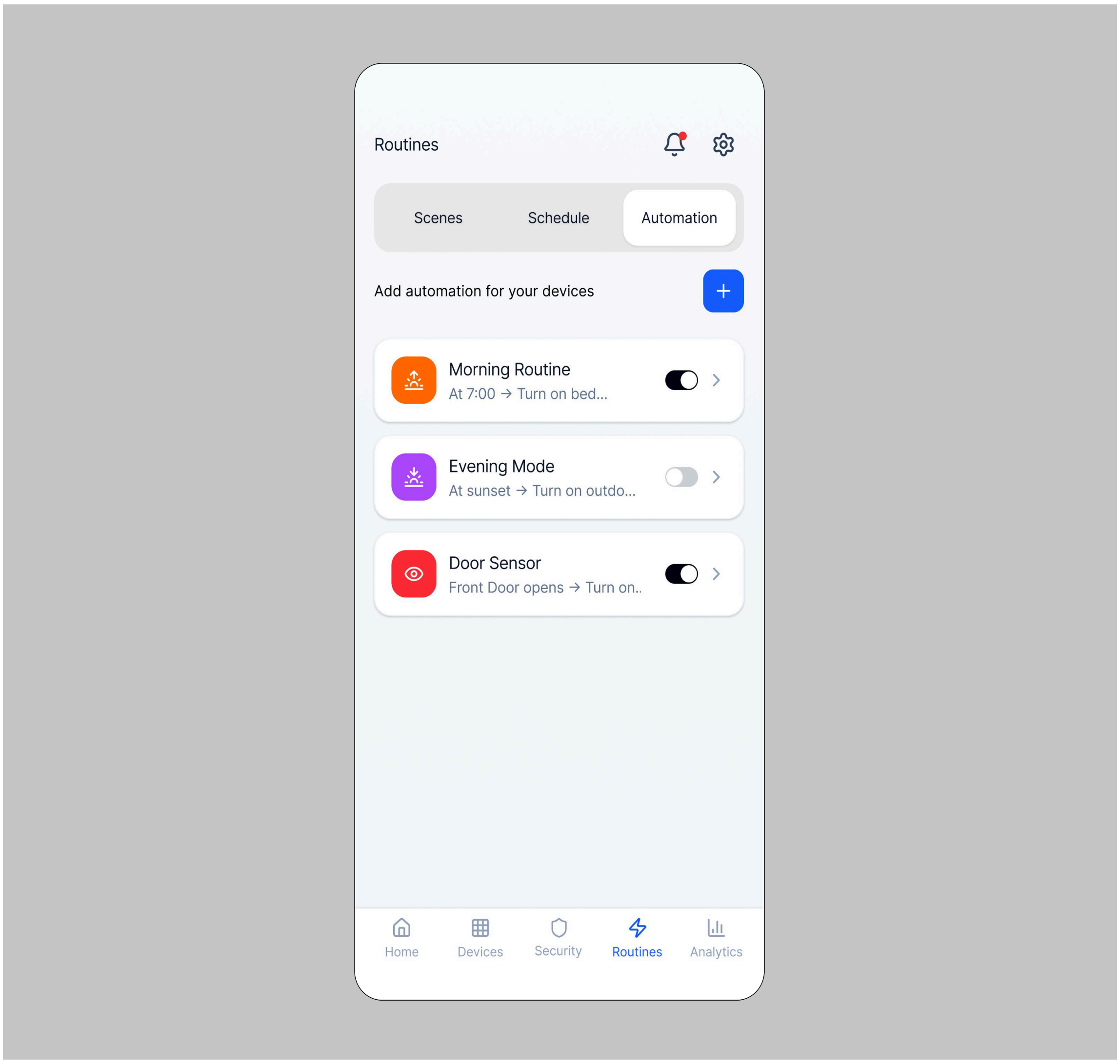

Figure 5.2.4.2: Routines Screen — Automation

5.4.5 Analytics Screen

The Analytics screen provides an overview of energy consumption and device activity across the home. The refined design integrates interactive charts that present data from energy sensors defined during system setup. Users can explore consumption through a calendar-based date selector, which replaced the more rigid labels found in the low-fidelity version.

The use of blue for selected states and green for consumption indicators creates a clear visual language for interpreting data. This screen supports Giulia's long-term goal of optimizing energy efficiency and allows for quick comparisons over time.

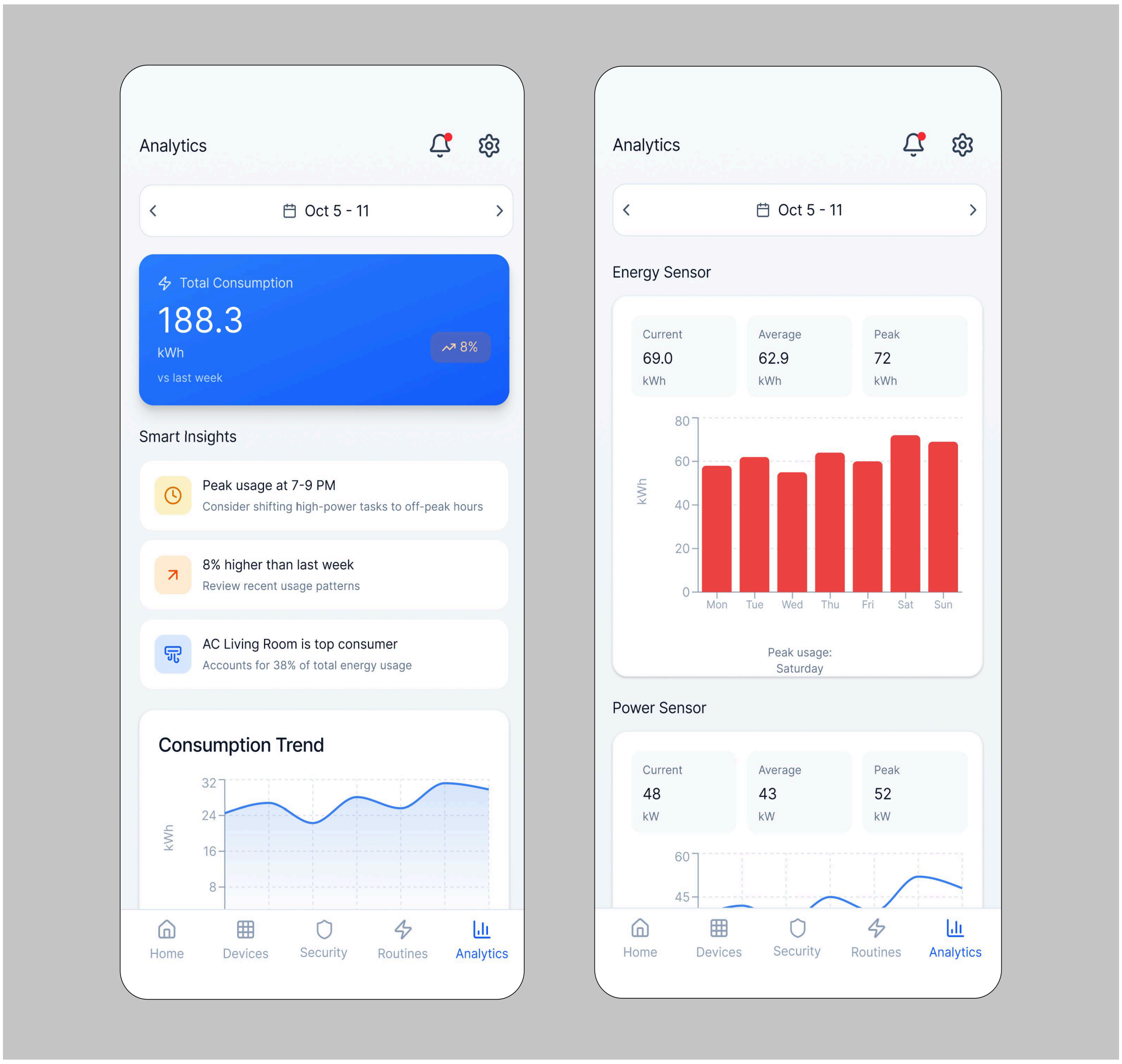

Figure 5.2.5: Security Screen

5.4.6 Notifications Screen

Notifications can be accessed from anywhere in the application. When the user taps the Notifications icon, a bottom sheet appears, displaying all received alerts. These notifications are interactive—allowing users to take relevant actions directly from the notification, depending on its type and purpose.

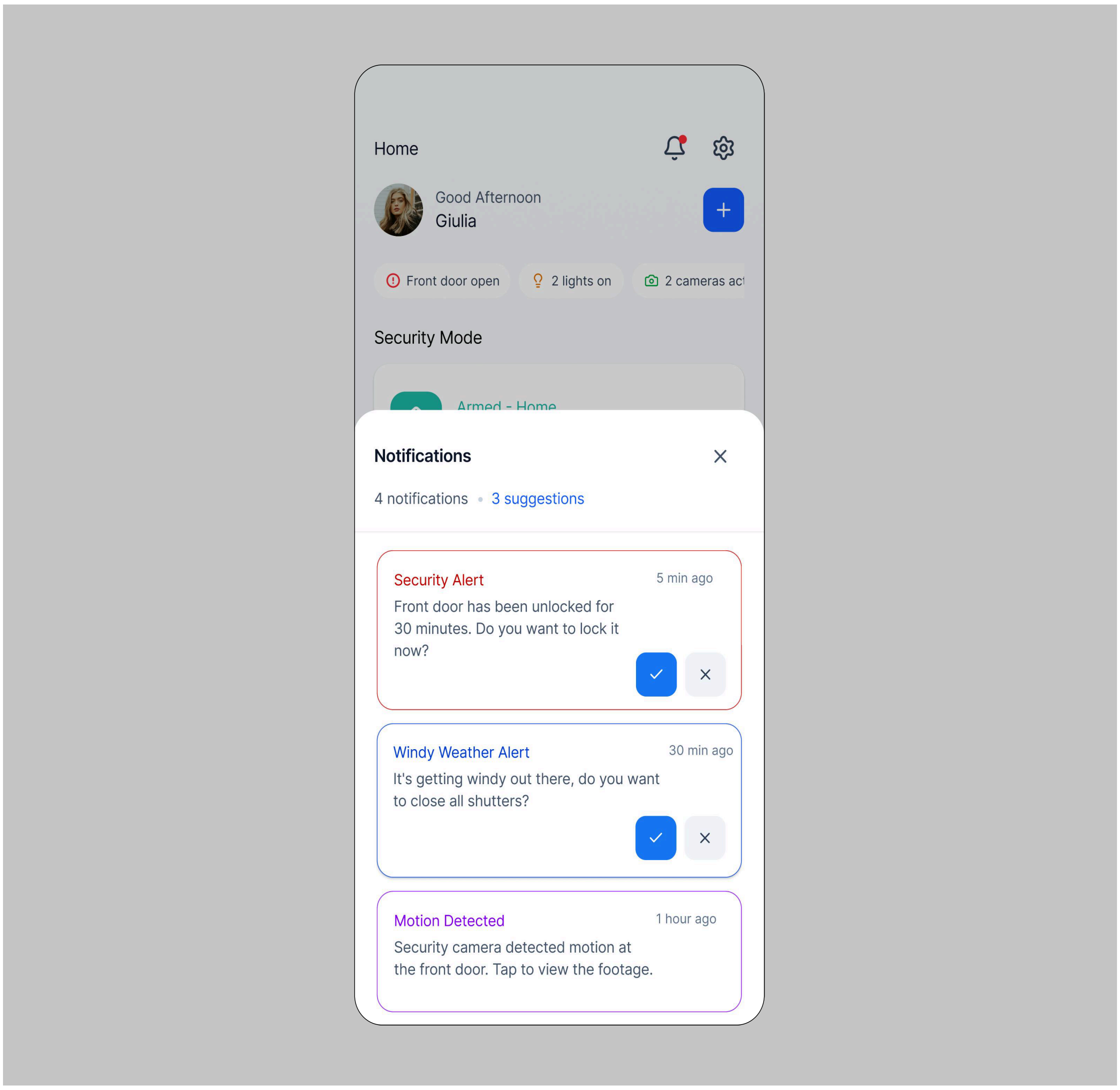

Figure 5.2.6: Notifications Screen

5.5 Interactive Prototype

The high-fidelity screens developed in Figma were connected to create an interactive prototype that simulates the intended behavior of the Smartotum application. All primary navigation paths—Home, Devices, Security, Routines, and Analytics—were linked using Figma's prototyping tools, enabling realistic transitions between screens. Interactive elements such as cards, buttons, toggles, chevrons, and mode selectors were assigned tap interactions that reflect their final functionality.

The prototype allows users to perform key tasks such as activating security modes, navigating between rooms and devices, enabling scenes, and creating schedules. State changes—such as turning a device on or off or activating a scene—are represented through updated colors, icons, and labels, replicating the real-time feedback intended for the final product.

This interactive prototype was also essential for conducting the usability testing presented in Chapter 6, as it provided participants with a realistic, task-driven environment in which they could navigate the system and complete typical smart-home interactions.

A link to the interactive prototype is provided below for reference:

Prototype

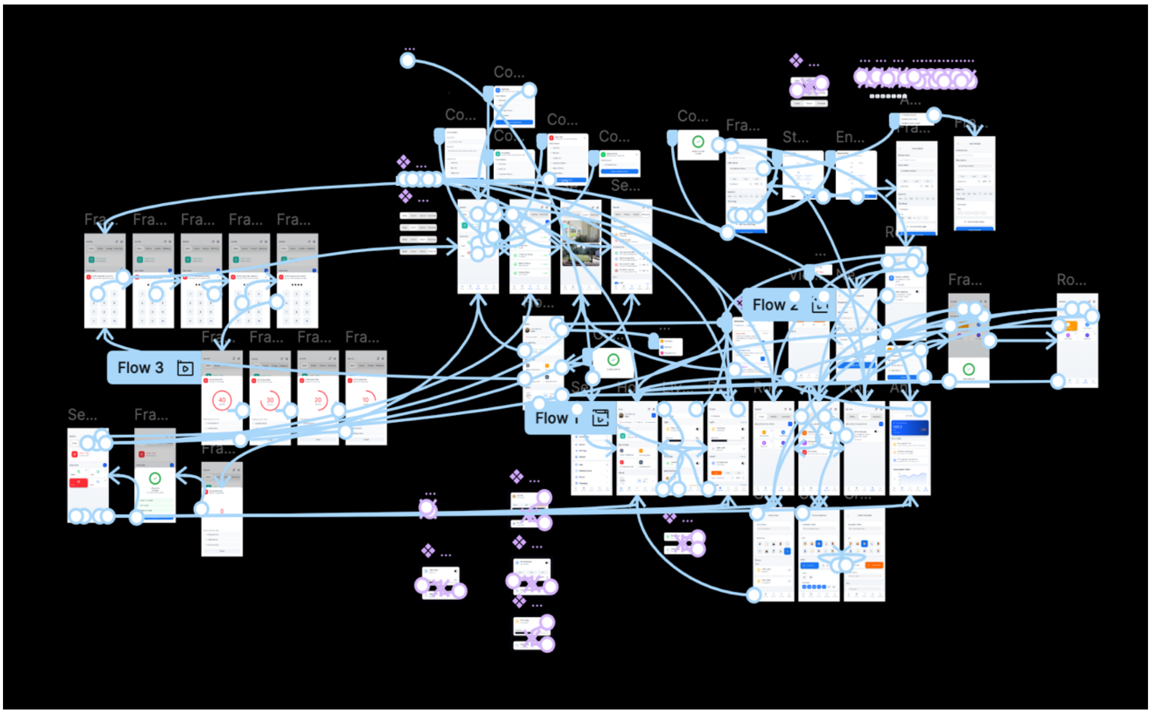

Figure 5.3: Overview of the Interactive Prototype in Figma
The image illustrates all screens and interaction connections used to simulate navigation across the Smartotum application.

Chapter 6

Test – User Evaluation

6.1 Introduction to the Test Phase

The Test phase represents the final stage of the Design Thinking framework and focuses on evaluating the effectiveness, clarity, and usability of the high-fidelity Smartotum prototype. After defining the requirements and developing the visual and interactive design, usability testing provides direct insight into how users understand and interact with the proposed interface. This phase is essential for verifying whether the design successfully supports the needs and behaviors identified in the Empathize and Define phases, particularly those represented by the user personas and scenarios.

The following sections detail the objectives of the evaluation, the methodology adopted, the participant profile, and the procedures followed during the usability testing sessions. The results collected through the tasks and the SUS questionnaire form the basis for the analysis presented in Chapter 7 [26].

6.2 Testing Objectives

The primary objective of the usability testing phase is to evaluate the clarity, efficiency, and overall usability of the high-fidelity Smartotum prototype. The testing stage verifies whether the proposed solutions effectively support real user interactions and align with the expectations of the intended audience.

More specifically, the usability test aims to:

1. Assess task efficiency and ease of navigation; determine whether users can successfully perform essential actions—such as activating security modes, managing devices, activating a scene, and creating schedules—without confusion or unnecessary steps.

2. Evaluate the clarity of visual hierarchy and information organization; understand whether the arrangement of modules, cards, actions, and labels supports quick recognition and decision-making.

3. Verify the intuitiveness of interaction patterns; examine how users respond to interface elements such as toggles, buttons, chevrons, and status indicators, and whether these elements correctly communicate interaction affordances.

4. Measure perceived usability using the System Usability Scale (SUS); obtain a standardized, quantitative usability score that reflects how users perceive the system's complexity, consistency, and overall ease of use.

5. Identify potential usability issues and improvement areas; gather qualitative feedback on aspects that may cause confusion, hesitation, or errors, informing recommendations for future refinements.

Together, these objectives ensure that the prototype is evaluated from both performance-based and perception-based perspectives, providing a reliable foundation for understanding the strengths and limitations of the current design before implementation.

6.3 Methodology

The usability evaluation was conducted using a task-based test combined with a standardized post-test questionnaire. The methodology was designed to balance academic rigor with practical constraints, allowing for the collection of both performance data and subjective assessments of usability. The test focused on the core interactions of the Smartotum prototype and was structured to provide reliable insights while remaining concise for participants.

6.3.1 Testing Approach

A combination of remote and in-person **usability tests** was adopted to observe participants' behavior while they interacted with the high-fidelity prototype developed in Figma. Each session was conducted individually through both in-person and remote sessions, which allowed participants to share their thoughts while performing tasks.

This approach enabled real-time observation of user actions, difficulties, and reasoning, while ensuring consistency across all sessions.

Participants were instructed to follow a **think-aloud protocol**, expressing their thoughts, expectations, and uncertainties during the tasks. This qualitative feedback provided additional insight into the clarity of navigation, the discoverability of controls, and the overall interaction experience.

At the end of the session, participants completed the **System Usability Scale (SUS)**, a standardized 10-item questionnaire used to measure perceived usability [26].

6.3.2 Tasks

Participants were asked to complete four short tasks representing essential interactions within the Smartotum ecosystem. These tasks were selected based on the user scenarios, interaction flows, and core functionalities of the prototype. Each task required users to navigate through the interface and manipulate or activate system features, allowing for observation of both navigation patterns and interaction clarity.

The tasks were:

Task 1 — Turn off all lights

The participant uses the Quick Actions section to turn off all lights in the home.

Task 2 — Activate "Away" Security mode

The participant is asked to switch to a different security mode (e.g., Away Mode) using the options available on the Home or Security screen.

Task 3 — Activate "Good Morning" scene

The participant navigates to the Scenes section (or in Home Screen), selects one of the available scenes (e.g., Good Morning), and activates it.

Task 4 — Create a "Summer" schedule for the Air Conditioner

The participant accesses the scheduling interface and simulates creating a new cooling schedule.

These tasks cover a range of common smart-home interactions, including navigating between sections, understanding system feedback, interpreting icons and labels, and completing multi-step workflows.

- Note: A full set of tests is available in Appendix A: Figma Prototype.

6.3.3 Evaluation Metrics

Both **quantitative** and **qualitative** measures were used to assess the usability of the prototype.

Quantitative Metrics

- **Task Completion Rate:** Whether the participant successfully completed each task.
- **Task Success Level:** Success, partial success, or failure is recorded for each task.
- **SUS Score:** A standardized score from 0 to 100 calculated from the participant's responses to the 10-item System Usability Scale [26].

Qualitative Metrics

- Observations of user behavior, hesitation, or confusion.
- Verbal feedback was gathered during the think-aloud process.
- Comments provided after the tasks, focusing on perceived clarity, ease of navigation, and overall impressions.

Together, these metrics provide a comprehensive understanding of the usability of the Smartotum interface, combining objective performance indicators with subjective perceptions of ease of use and satisfaction.

6.4 Participants

Five participants were recruited to take part in the usability evaluation. This sample size aligns with widely accepted guidelines in usability research, which indicate that a small number of participants—typically between three and five—is sufficient to uncover the majority of usability issues in a formative evaluation. This sample size aligns with Nielsen's widely accepted guideline, which states that testing with five users is sufficient to uncover approximately 80% of usability problems in a formative evaluation [27].

Participants were aged between **23 and 34**, representing young adults who are familiar with mobile applications and represent a relevant demographic for smart-home technology adoption. Their level of smart home experience ranged from **mid to high**, with all participants having previously interacted with at least one smart-home device or system. This level of experience ensured that participants could understand the context of the tasks and provide meaningful feedback regarding the usability and clarity of the interface.

No personal identifying information was collected during the evaluation. Participants were identified only by their demographic characteristics and their qualitative and quantitative performance during the test. This profile provided a suitable basis for assessing the usability of the Smartotum prototype and evaluating whether the interface supports the expectations and mental models of users with moderate smart home familiarity.

6.5 Test Procedure

The usability testing sessions followed a structured procedure designed to ensure consistency across participants while allowing for natural interaction with the Smartotum prototype. Sessions took place partially remote and partially in person, and were conducted individually.

The procedure consisted of the following steps:

1. Introduction and Briefing

Participants were welcomed and informed about the purpose of the study, which was to evaluate the usability of a smart-home mobile interface. They were assured that the evaluation concerned the interface—not their performance—and that their responses would remain anonymous.

2. Explanation of the Testing Format

Before beginning the tasks, participants were instructed on how to navigate through the prototype in Figma and were encouraged to verbalize their thoughts during the interaction, following a think-aloud protocol. This ensured that difficulties, confusions, or expectations could be recorded in real time.

3. Task Execution

Participants completed the four predefined tasks:

1. Activate “Away” security mode
2. Turn off all lights using Quick Actions
3. Activate “Good Morning” scene
4. Create a “Summer” schedule for the Air Conditioner

The moderator observed navigation patterns, hesitation points, and any errors or misunderstandings encountered during the tasks.

4. Post-Task Feedback

After completing all tasks, participants were asked a few brief, open-ended questions about their overall impressions of the interface, such as clarity, ease of navigation, or any elements they found confusing or intuitive. This step provided additional qualitative insights.

5. Completion of the SUS Questionnaire

Participants then completed the **System Usability Scale (SUS)** through an online Google Form. Participants were asked to rate 10 standard statements using a 5-point Likert scale ranging from "Strongly Disagree" (1) to "Strongly Agree" (5) [26].

6. Session Closing

Participants were thanked for their time and contribution. No personal data beyond age range and smart home experience level was collected.

Chapter 7

Results and Discussion

7.1 Introduction

This chapter presents the results of the usability evaluation conducted on the Smartotum high-fidelity prototype and discusses their implications for the design of the smart-home interface. The findings derive from quantitative measures collected during task execution and from the System Usability Scale (SUS) [26], as well as qualitative insights obtained through observations and participants' verbal feedback during the think-aloud sessions. Together, these results provide a comprehensive understanding of how effectively the prototype supports the needs, expectations, and behaviors identified earlier in the design process. The chapter concludes by interpreting the findings in relation to the design principles established in Chapter 3 and the structural decisions made during the Ideate and Prototype phases.

7.2 Quantitative Results

7.2.1 Task Completion

All participants completed the four predefined tasks. Table 7.1 summarizes the success rate for each task.

Task	Success	Partial Success	Failure
Activate “Away” security mode	5	0	0
Turn off all lights	5	0	0
Activate a scene	4	1	0
Create “Summer” schedule	5	0	0

Table 7.1: Task Completion Summary

(Success = completed without help; Partial success = required minor guidance; Failure = unable to complete)

Participants performed the first two tasks with full success, indicating that core controls—security modes and quick device actions—were easily accessible and recognizable. Most users also successfully activated a scene, though one participant required minor clarification, suggesting that first-time users may need a brief onboarding to understand the functional concept of “Scenes” in smart-home ecosystems. Finally, all users completed the scheduling task, reinforcing the clarity and adaptability of the configuration workflow.

7.2.2 SUS Score

After completing the tasks, participants filled in the System Usability Scale (SUS). The individual SUS scores were calculated following Brooke’s scoring procedure, and the overall SUS score was obtained by averaging the participants’ results [26].

Participant	**SUS Score**
P1	95
P2	80
P3	97.5
P4	70
P5	80
Mean	**84.5**

Table 7.2: Individual SUS Scores

The mean SUS score obtained was **84.5**, corresponding to a usability rating of "**Excellent**" based on industry-standard interpretation scales (Brooke 1996). Scores above 68 are generally considered acceptable, while scores above 80 indicate excellent perceived usability.

7.3 Qualitative Findings

Qualitative insights from the think-aloud sessions provided additional depth to the quantitative results. Participants' comments and observed behaviors were analyzed thematically.

Overall Clarity and Navigation

Participants consistently described the interface as "clean," "well organized," and "easy to follow." The bottom navigation bar helped users develop an immediate mental model of the main sections. The introduction of a dedicated Security tab was perceived as logical and aligned with the natural priority of security-related actions in smart-home management.

Discoverability of Actions

Quick Actions were highly discoverable and appreciated for their efficiency. Several users preferred using Quick Actions over navigating into sections, demonstrating the value of placing frequently used functions prominently. The chevron indicators also improved clarity by signaling where additional information or configuration options were available.

Feedback and Status Visibility

Visual feedback—such as color changes, icon highlights, and explicit labels like "Armed – Home"—was praised for reinforcing user confidence, especially regarding security actions. This feedback contributed significantly to users feeling "reassured" and "in control," consistent with the needs expressed by both personas.

Areas of Confusion

A recurring issue emerged when participants interacted with the "Good Morning" scene. Four out of five participants were unfamiliar with the conceptual category of "Scenes" in smart-home systems. While they completed the task, their hesitation indicates that scenes may require optional introductory guidance or a short explanation during onboarding.

Chapter 8

Conclusions and Future Work

8.1 Conclusions

This thesis presented the redesign of the Smartotum smart-home application using a Design Thinking approach. Beginning with contextual research and benchmarking, the work identified key user needs in the Italian smart-home landscape, leading to the formulation of clear design principles and requirements. Through iterative ideation, wireframing, and high-fidelity prototyping, the project produced a refined interface focused on clarity, simplicity, consistency, and efficient access to frequent actions.

The usability evaluation confirms the effectiveness of the design. All participants completed the tasks without major issues, and the SUS score of **84.5** indicates excellent perceived usability. Qualitative feedback reinforces this result, highlighting strong clarity, discoverability, and reassuring feedback—especially in security-related functions. The redesign successfully transforms the early functional prototype into a coherent, user-centered interface aligned with real smart-home usage patterns.

8.2 Limitations

Several limitations should be considered when interpreting the results.

- The participant sample was limited to five users, appropriate for formative testing but not statistically representative.
- The Figma prototype lacked full functionality, preventing the evaluation of features requiring text input or complex device logic.

Despite these constraints, the evaluation provides valuable insights that strongly support the proposed design.

8.3 Future Work

Building on the findings of this thesis, several opportunities exist for further development:

- **Backend integration:** Implementing the prototype into a functional mobile application for real-world testing.
- **Enhanced Scenes onboarding:** Providing an optional tutorial after starting the app to introduce scene-based automation to unfamiliar users.
- **Expanded Analytics:** Integrating device-level energy breakdowns, historical patterns, and predictive suggestions.
- **Advanced scheduling:** Supporting more complex automation logic and improved multi-step workflows.
- **Accessibility improvements:** Adding features such as dynamic text sizing, dark mode, and voice-based interaction.

Appendix A: Figma Prototype

A.1 Figma Prototype Link

The interactive prototype can be accessed at the following link:
Figma file: Smartotum Hi-Fi Prototype
This link provides access to the full interactive prototype used during user testing.

A.2 Prototype Screenshots

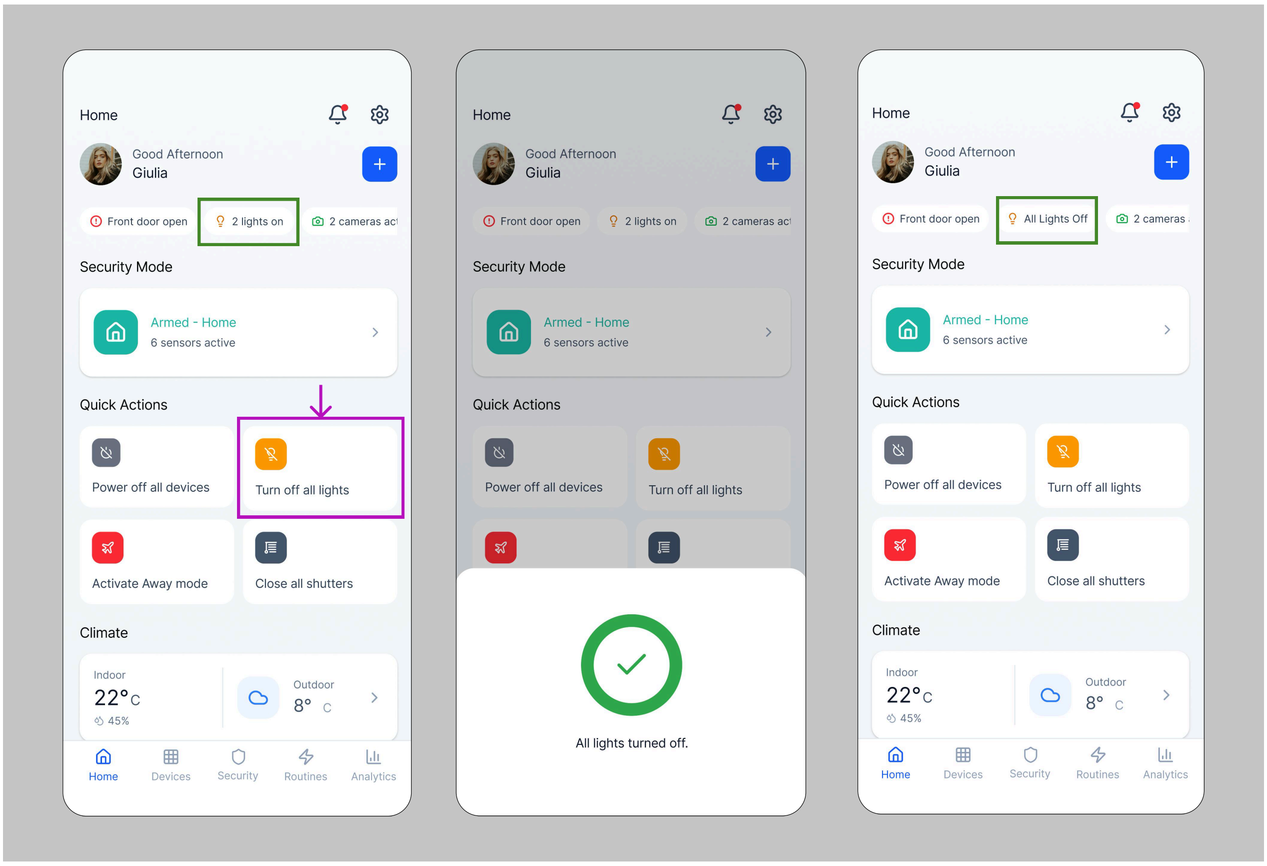

Figure A.1: Turn off all lights quick action

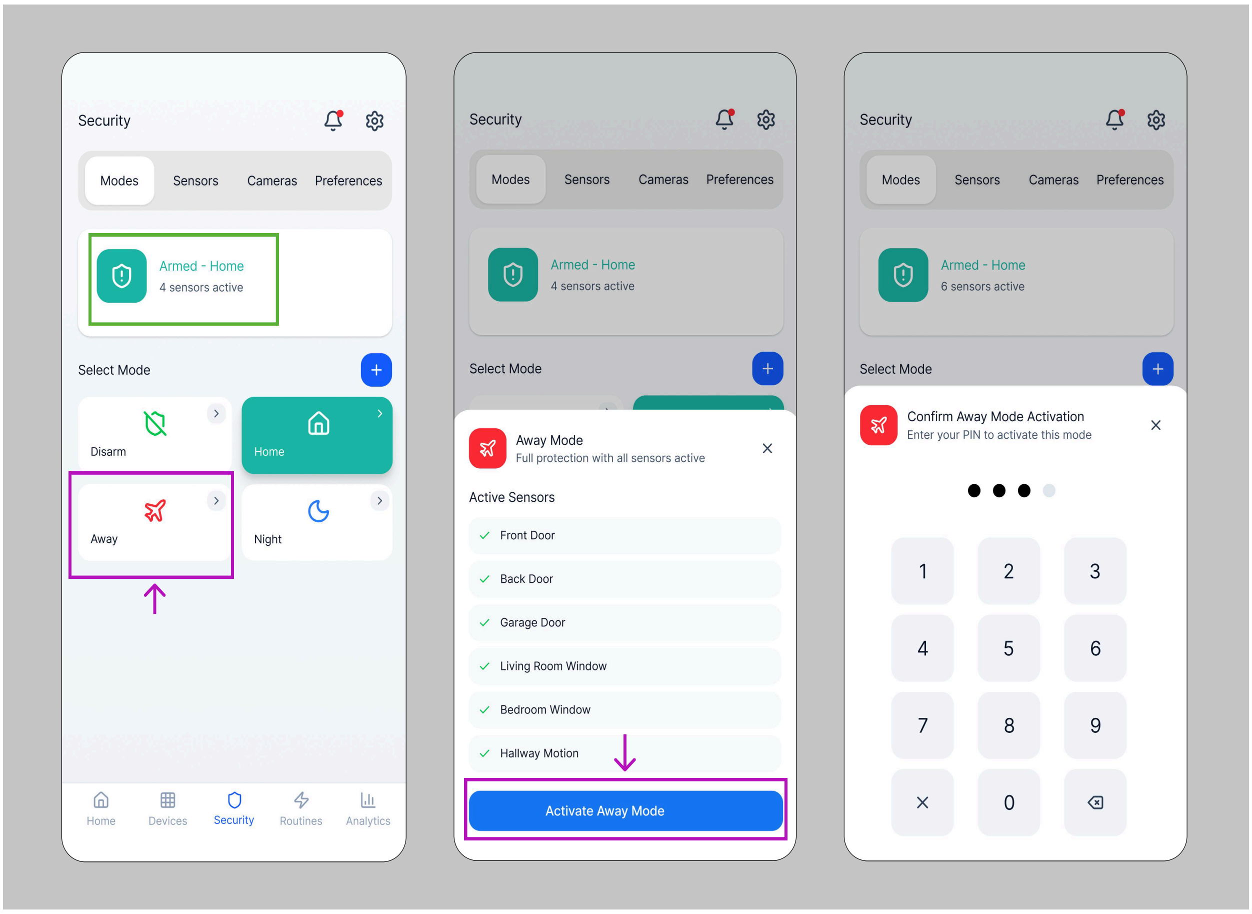

Figure A.2.1: Activate “Away” Security Mode – First Screen

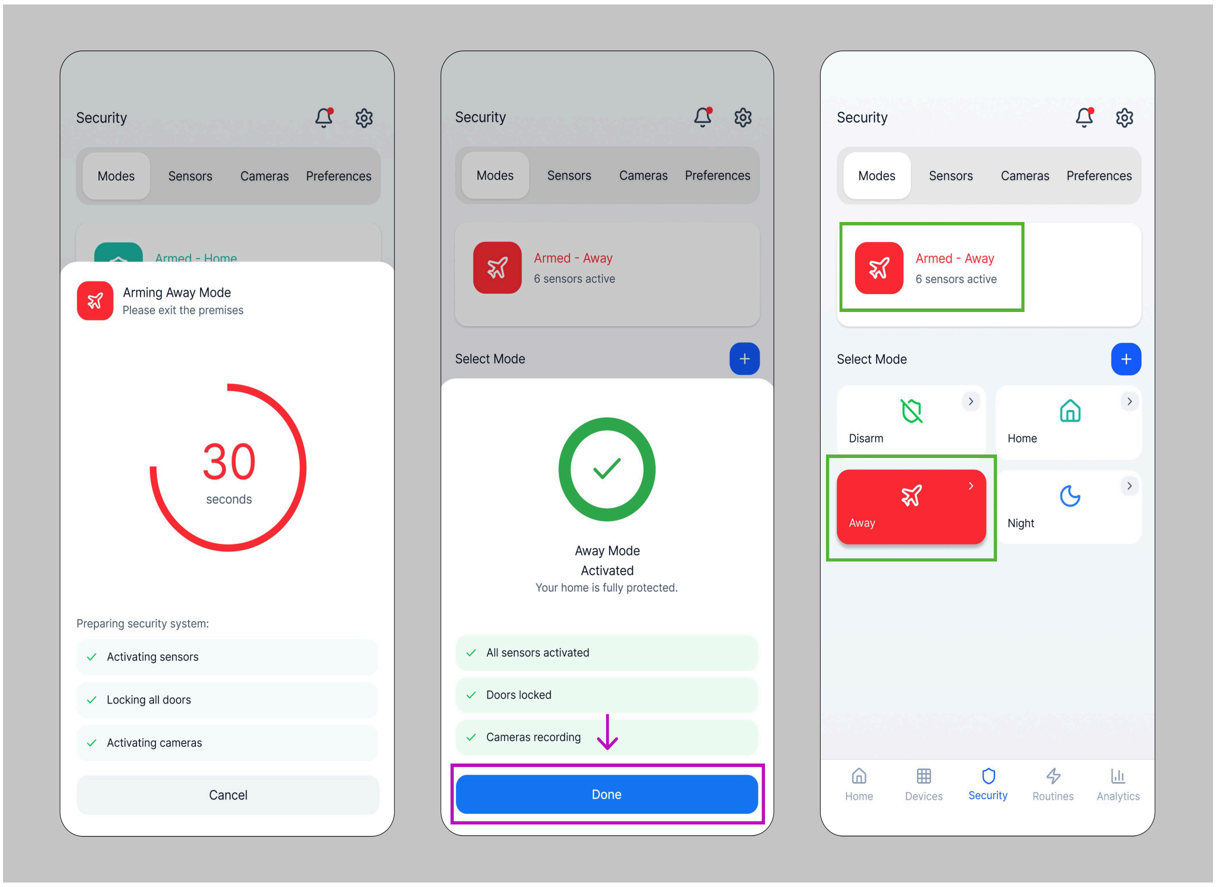

Figure A.2.2: Activate "Away" Security Mode – Second Screen

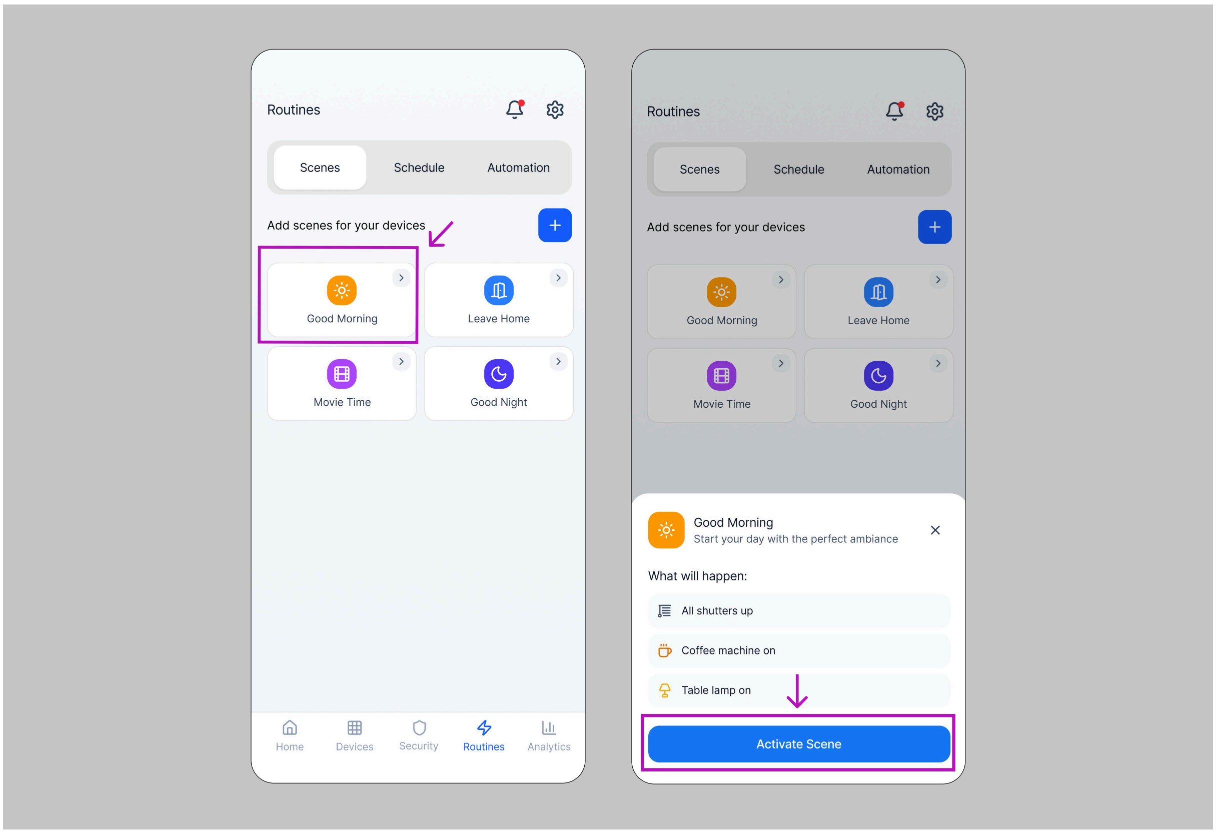

Figure A.3.1: Activate "Good Morning" Scene – First Screen

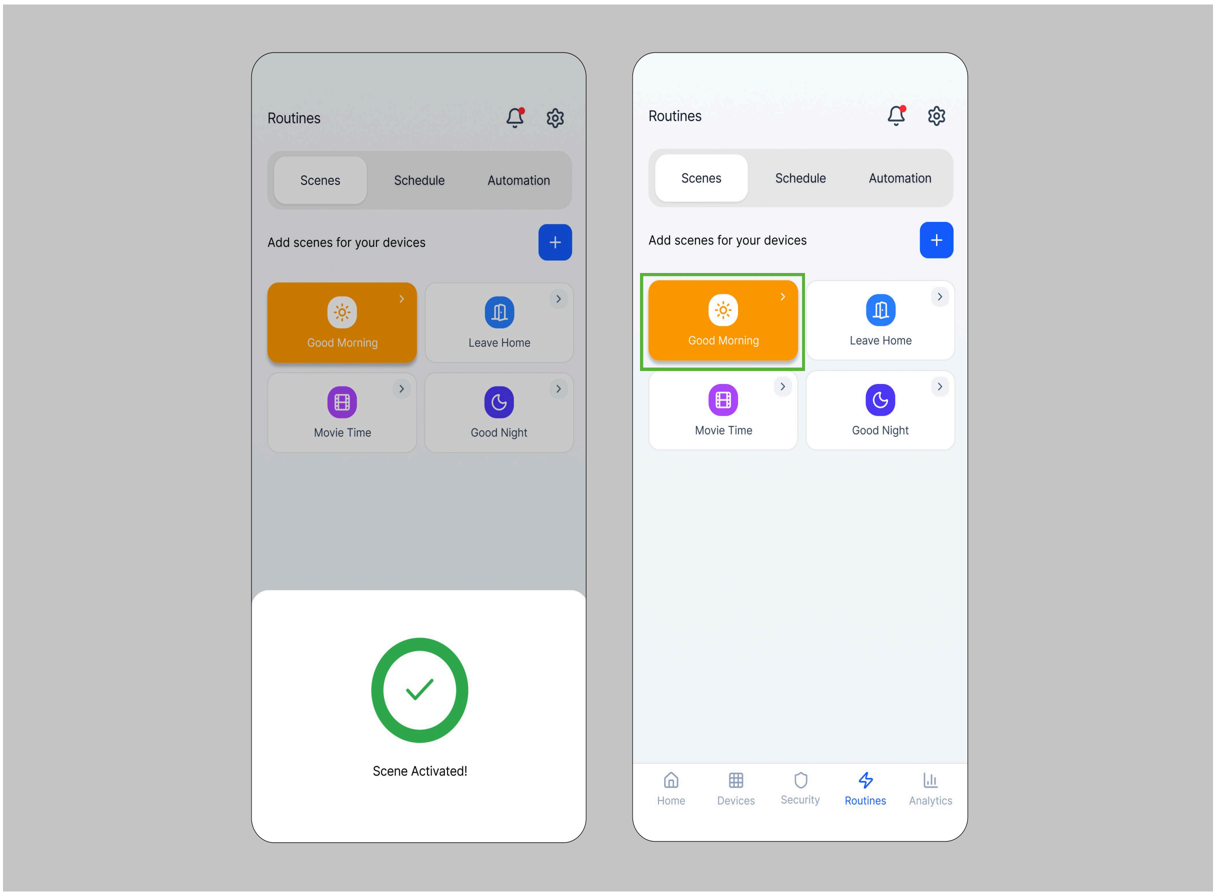

Figure A.3.2: Activate "Good Morning" Scene – Second Screen

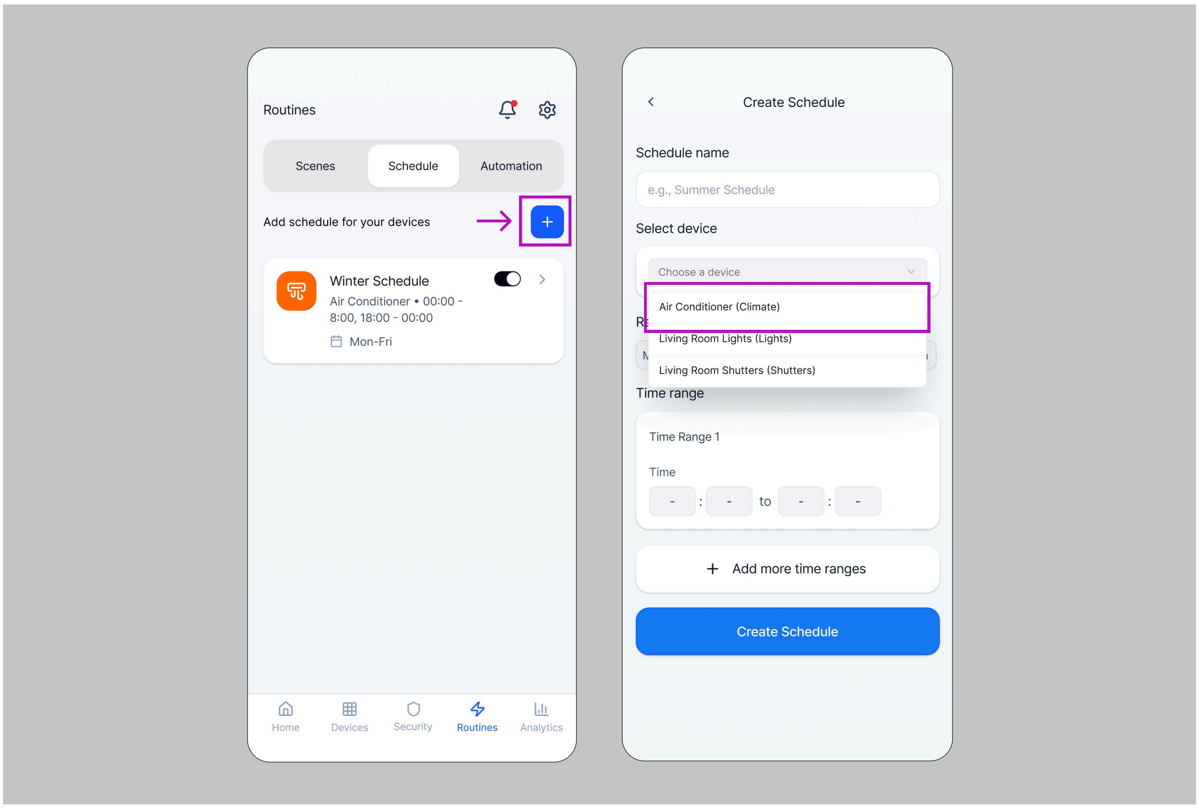

Figure A.4.1: Create a "Summer" Schedule – First Screen

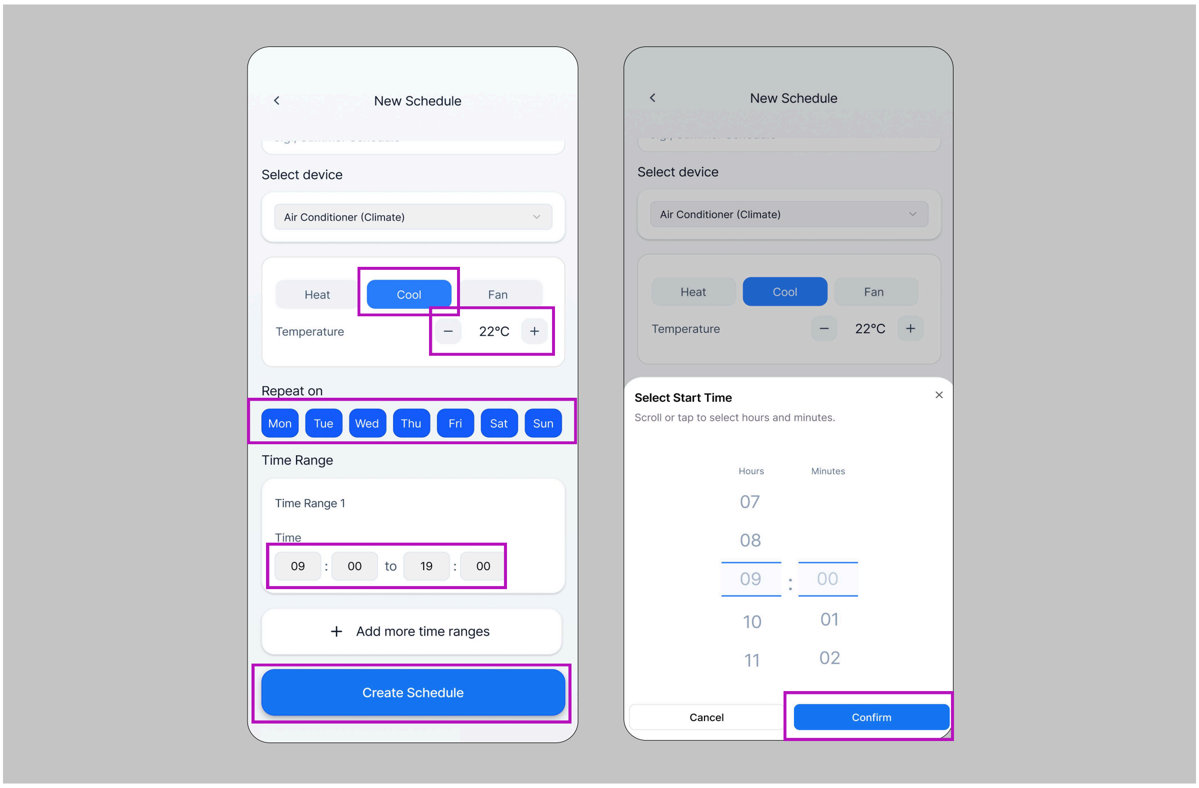

Figure A.4.2: Create a “Summer” Schedule – Second Screen

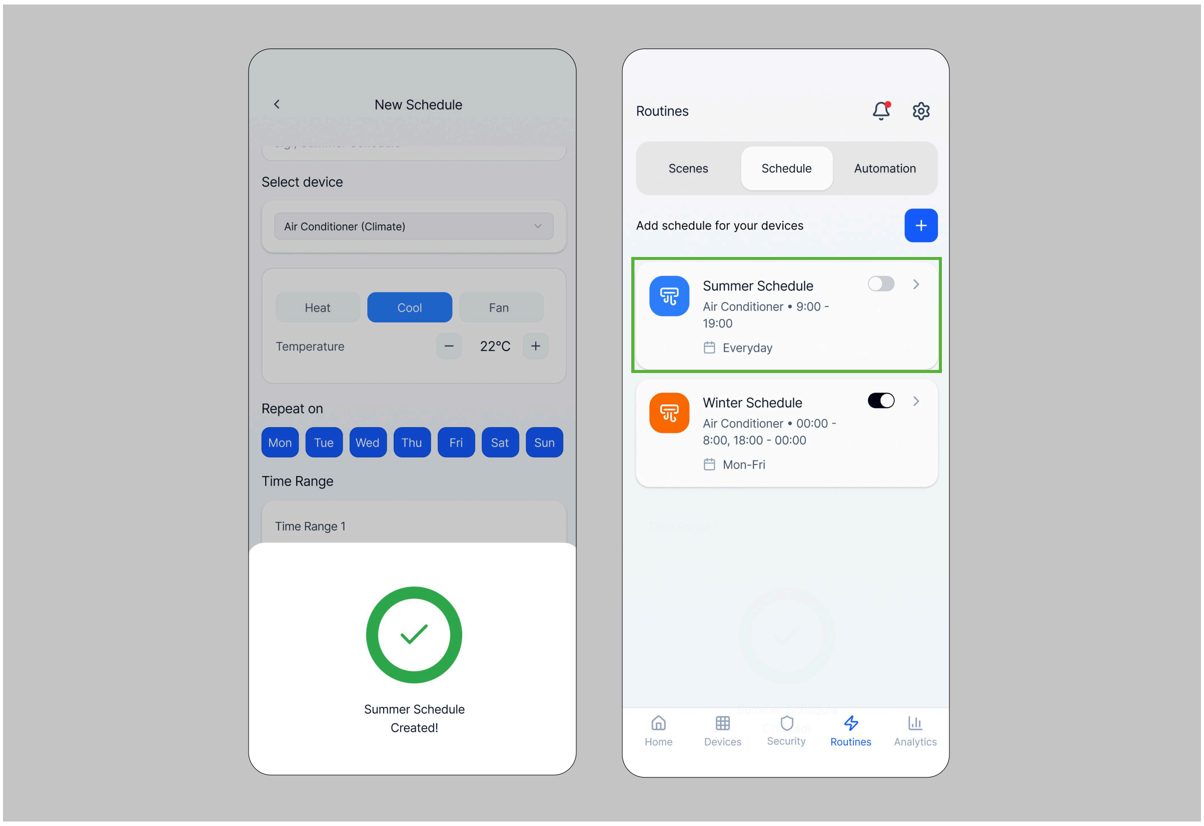

Figure A.4.3: Create a "Summer" Schedule – Third Screen

Bibliography

[1] BVA Doxa, “6 italiani su 10 possiedono oggetti smart in casa. Alta la propensione all’acquisto in futuro,” Feb. 25, 2025. Available: https://www.bva-doxa.com/6-italiani-su-10-possiedono-oggetti-smart-in-casa-alta-la-propensione-allacquisto-in-futuro/

[2] Fantini Cosmi S.p.A., “Mercato della Smart Home: le tendenze della casa ‘intelligente’,” Feb. 16, 2024. Available: https://www.fantinicosmi.it/mercato-smart-home/

[3] A. Vacanti, “How smart is the Italian domestic environment? A quantitative study,” in *Proceedings of IASDR 2023: Life-Changing Design*, Milan, Italy, Oct. 9–13, 2023, doi:10.21606/iasdr.2023.206. Available: https://dl.designresearchsociety.org/iasdr/iasdr2023/fullpapers/46/

[4] Osservatorio Internet of Things, POLIMI School of Management, “Nel 2024 il mercato dell’Internet of Things raggiunge 9,7 mld di euro, +9%,” *Comunicato stampa*, Apr. 2025. Available: https://www.osservatori.net/comunicato/internet-of-things/internet-of-things-italia-mercato/

[5] NextMSC, “Italy Smart Home Market Value Analysis | 2024–2030,” 2025. Available: https://www.nextmsc.com/report/italy-smart-home-market

[6] Mordor Intelligence, “Italy Smart Home Market Size, Outlook, Forecast & Global ...,” Jun. 26, 2025. Available: https://www.mordorintelligence.com/industry-reports/italy-smart-home-market

[7] SMARTOTUM S.r.l., “Smartotum – Una app per tutto: gestisci la tua casa con Smartotum,” 2025. Available: https://www.smartotum.com/

[8] Politecnico di Torino, "La domotica del futuro passa da Smartotum, spin-off del Politecnico di Torino e del CNR," *PoliFlash*, Mar. 27, 2024. Available: https://www.polito.it/ateneo/comunicazione-e-ufficio-stampa/poliflash/la-domotica-del-futuro-passa-da-smartotum-spin-off-del

[9] Euronews Next, "Survey: Most Europeans are worried about their digital privacy," Jun. 12, 2025. Available: https://www.euronews.com/next/2025/06/12/survey-most-europeans-are-worried-about-their-digital-privacy-and-its-impacting-how-they-u

[10] Smart Building Expo, "Smartotum: la smart home completa, wireless e attenta alla privacy," Sept. 9, 2025. Available: https://smartbuildingexpo.it/domotica/smartotum-la-smart-home-completa-wireless-e-attenta-alla-privacy/

[11] T. Brown, "Design thinking," *Harvard Business Review*, vol. 86, no. 6, pp. 84–92, Jun. 2008. Available: https://hbr.org/2008/06/design-thinking

[12] D. Marikyan, S. Papagiannidis, and E. Alamanos, "A systematic review of the smart home literature: A user perspective," *Technological Forecasting and Social Change*, vol. 138, pp. 139–154, 2019, doi: 10.1016/j.techfore.2018.08.015.. Available: https://www.sciencedirect.com/science/article/abs/pii/S0040162517315676

[13] N. Yu, Z. Ouyang, and H. Wang, "Study on smart home interface design characteristics considering the influence of age difference: Focusing on sliders," *Frontiers in Psychology*, vol. 13, Art. no. 828545, Mar. 22, 2022, doi: 10.3389/fpsyg.2022.828545. Available: https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2022.828545/full

[14] M. M. Fakhimi, A. Hughes, and A. M. Gustavson, "Evaluating smart home usability and accessibility in early detection and intervention of mental health challenges among older adults: A narrative review and framework," *J. Ageing Longev.*, vol. 5, no. 1, Art. no. 3, Jan. 24, 2025, doi: 10.3390/jal5010003. Available: https://www.mdpi.com/2673-9259/5/1/3

[15] N. Samancioglu, K. Väänänen, and R. Castano De la Rosa, "Aligning smart home technology attributes with users' preferences: A literature review," *Intelligent Buildings International*, vol. 16, no. 3, pp. 129–143, 2024, doi: 10.1080/17508975.2024.2418648. Available: https://www.tandfonline.com/doi/full/10.1080/17508975.2024.2418648

[16] D. A. Norman, *The Design of Everyday Things*, rev. and expanded ed. Cambridge, MA, USA: MIT Press, 2013. Available: https://mitpress.mit.edu/9780262525671/the-design-of-everyday-things/

[17] J. Nielsen, "Usability 101: Introduction to usability," *Nielsen Norman Group*, Jan. 3, 2012. Available: https://www.nngroup.com/articles/usability-101-introduction-to-usability/

[18] M. Buzzi, B. Leporini, and C. Meattini, "Design guidelines for web interfaces of home automation systems accessible via screen reader," *Journal of Web Engineering*, vol. 18, nos. 4–6, pp. 477–512, 2019, doi: 10.13052/jwe1540-9589.18468. Available: https://iris.cnr.it/retrieve/588dd462-f422-4bb4-a3e3-df6889394260/prod_408459-doc_143355.pdf

[19] M. Kurosu and K. Kashimura, "Apparent usability vs. inherent usability: Experimental analysis on the determinants of the apparent usability," in *Proc. CHI '95 Conf. Companion on Human Factors in Computing Systems (CHI '95)*, Denver, CO, USA, May 1995, pp. 292–293, doi: 10.1145/223355.223680. [Online]. Available: https://dl.acm.org/doi/10.1145/223355.223680

[20] J. Nielsen, "10 usability heuristics for user interface design," *Nielsen Norman Group (Alertbox)*, Apr. 24, 1994. Available: https://www.nngroup.com/articles/ten-usability-heuristics/

[21] W3C, "Web Content Accessibility Guidelines (WCAG) 2.1," *W3C Recommendation*, Jun. 5, 2018, revised May 6, 2025. Available: https://www.w3.org/TR/WCAG21/

[22] T. Tullis and W. Albert, *Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics*, 2nd ed. Amsterdam, The Netherlands: Morgan Kaufmann (Elsevier), 2013. [Online]. Available:

https://www.sciencedirect.com/book/9780124157811/measuring-the-user-experience

[23] T. Brown, “Design thinking,” *Harvard Business Review*, vol. 86, no. 6, pp. 84–92, Jun. 2008. Available: https://hbr.org/2008/06/design-thinking

[24] J. J. Garrett, *The Elements of User Experience: User-Centered Design for the Web and Beyond*, 2nd ed. Berkeley, CA, USA: New Riders, 2011. Available: https://ptgmedia.pearsoncmg.com/images/9780321683687/samplepages/0321683684.pdf

[25] Lucide, “Lucide – Open-source icon library,” 2024. Available: https://lucide.dev/

[26] J. Brooke, “SUS: A ‘quick and dirty’ usability scale,” in *Usability Evaluation in Industry*, P. W. Jordan, B. Thomas, B. A. Weerdmeester, and A. L. McClelland, Eds. London, U.K.: Taylor & Francis, 1996, pp. 189–194.

[27] J. Nielsen, “Why you only need to test with 5 users,” *Nielsen Norman Group*, Mar. 19, 2000. Available: https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/