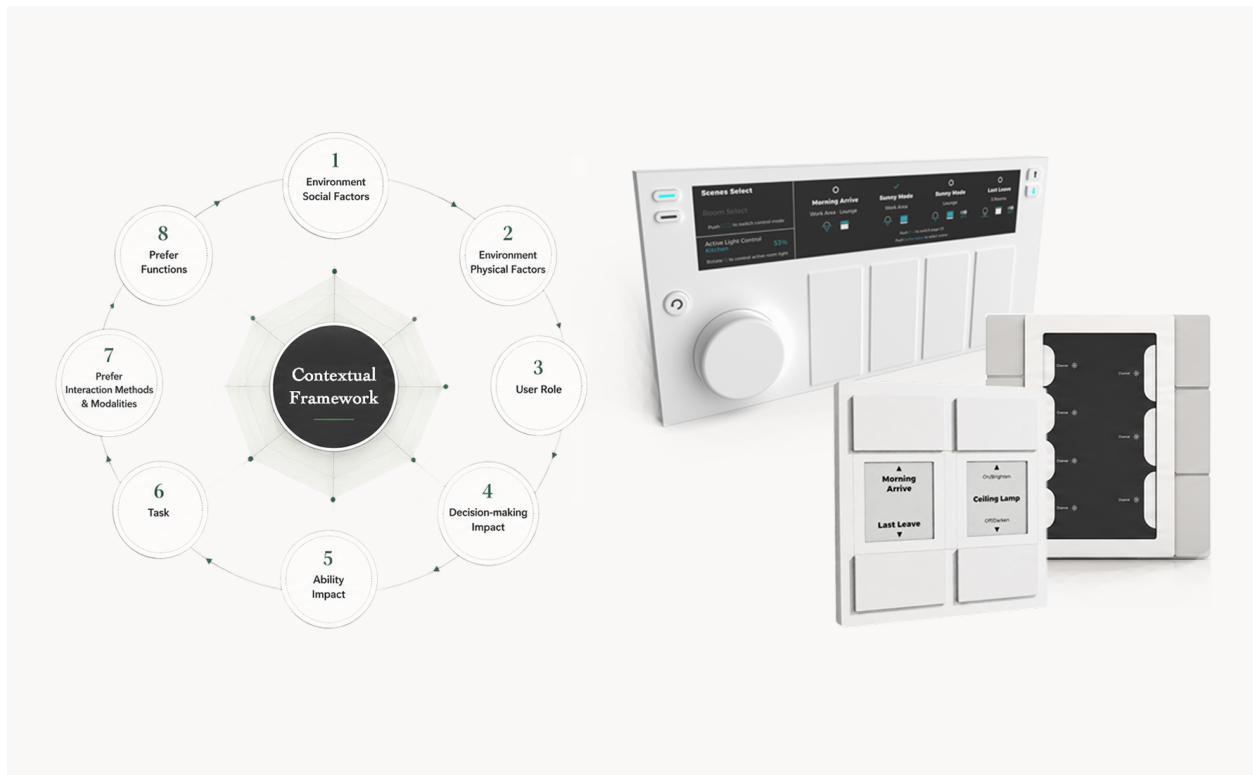




Contextual Factors influencing Smart Environment Control Panel

A research and design study on smart control panels in multi-user environments

Master's thesis in Industrial Design Engineering

Xunan Mao
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DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE

CHALMERS UNIVERSITY OF TECHNOLOGY
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Abstract

Indoor Internet of Things (IoT) control units are increasingly used to manage connected systems such as lighting, temperature, window blinds, and scene (scenario) settings. However, the same control unit may be used across very different environments, from private rooms to shared or public spaces. In these situations, interaction requirements are shaped not only by the system being controlled, but also by users, roles, tasks, physical conditions, social expectations, and responsibility.

This thesis investigates which context-of-use factors affect interaction requirements for indoor IoT control units, how they do so, and how these factors can be translated into control-and-feedback design. The project developed a context-to-interaction framework and applied it to the design of two smart control unit concepts: one framework-driven concept and one business-informed concept. The concepts were evaluated through hotel room and hotel lobby scenarios.

The evaluation showed a trade-off between first-use intuitiveness and cross-contextual stability. The business-informed concept was easier to understand at first time use, while the framework-driven concept remained more stable when the user role, context, or task goal changed. The thesis contributes a practical framework for analyzing contextual demands and translating them into design guidance for indoor IoT control units.

Keywords: IoT control unit, context of use, smart environment control, cross-context interaction, interaction design.

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This gratitude is also extended to the two anonymous supervisors at the anonymous partner company for enabling work with a real design case. Insights, feedback, and practical constraints from this collaboration were valuable in connecting the research framework to an actual product development context.

Gratitude is also extended to all participants in surveys, interviews, observations, scenario enactments, and concept evaluations. Their experiences, opinions, and reflections provided essential input for understanding the use of smart control units across different contexts.

Xunan Mao and Malkolm Ahlberg, Gothenburg, June 2026

List of Acronyms

Below is the list of acronyms that have been used throughout the thesis, listed in alphabetical order:

IoT	Internet of Things
UX	User Experience
ISO	International Organization for Standardization
HBI	Human-Building Interaction
HCI	Human-Computer Interaction
UI	User Interface
LCD	Liquid Crystal Display
LED	Light Emitting Diode
OLED	Organic Light Emitting Diode
TFT	Thin Film Transistor
TFT LCD	Thin Film Transistor Liquid Crystal Display

Nomenclature

Below is the nomenclature of the symbols and formulas used in the calculation parts of this thesis.

Symbols

R	User's sense of responsibility
A	User's sense of autonomy
E	User's sense of self-efficacy
+	High or supporting level of a contextual factor
–	Low or non-supporting level of a contextual factor
N/A	Not applicable factor, excluded from the calculation
$n_{\text{applicable}}$	Number of applicable factors included in the calculation

Formulas

Social factor score	A supporting state is counted as $1/n_{\text{applicable}}$, a non-supporting state is counted as 0, and N/A is excluded. If $n_{\text{applicable}} = 0$, the sense is treated as N/A .
Weighted Dimension Score	$\text{Weighted Dimension Score} = \frac{\text{Dimension Weight}}{\text{Total Task Weight}} \times \text{Participant Rating}$
Participant Total Score	$\text{Participant Total Score} = \sum \text{Weighted Dimension Scores}$

Index Score

$$\text{Index Score} = \frac{\sum \text{Weighted Dimension Scores of All Participants}}{\text{Number of Participants}}$$

Use of AI Tools

During the preparation of this thesis, translation and grammatical correction tools provided by Google and Overleaf were utilized for language accuracy. OpenAI's ChatGPT service was employed to assist with language refinement and text structure adaptation for Overleaf compatibility.

The authors retain full responsibility for the content of the thesis. All research decisions, data collection, analysis, design decisions, figures, evaluation results, interpretations, and final conclusions were conducted by the authors. AI tools were not used as a substitute for research activities, empirical data collection, or academic judgment.

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1

Introduction

Digital technologies are becoming increasingly embedded in everyday life, moving beyond singular devices or isolated locations and becoming part of larger Internet of Things (IoT) networks. As IoT systems expand across domestic, organizational, and urban settings, there is an increasing need to adapt, coordinate, and oversee connected devices and environmental systems. In this situation, the question of how to provide appropriate ways of control becomes a central issue in interaction design.

Interaction quality cannot be separated from context. Usability standards define interactive systems in relation to specific users, goals, and contexts of use (International Organization for Standardization, 2018, 2019). Context-aware computing also describes context as information that characterizes a situation relevant to interaction (Dey, 2001). These perspectives suggest that the same type of control device may create different interaction requirements depending on the situation, user groups, tasks, and type of control involved.

This issue becomes especially visible in indoor environment control. Smart product-service systems are highly context-dependent, and smart building management systems are expected to adapt building resources to occupants' needs (Carrera-Rivera et al., 2022; Taboada-Orozco et al., 2024). This means that the same IoT control unit may appear in different environments while controlling similar objects, such as lighting, blinds, temperature, or scenes. However, the interaction situation may still be fundamentally different. A control unit used in a private room, a hotel room, a shared office, or a semi-public lobby may involve different users, different levels of permission, different social expectations, and different consequences of action.

At the same time, indoor control interfaces are not always self-explanatory for end users. In shared office spaces, conventional thermostats have been reported as inadequate due to issues such as inaccessibility, poor availability of information, and low responsiveness, leaving users uncertain about how the system operates and whether their commands have any effect (Balaji et al., 2016). In automated buildings, occupants may override thermostat settings in response to discomfort, but such overrides do not necessarily satisfy occupants' needs or meet the building's control requirements (Kane & Sharma, 2019). In non-domestic academic buildings, existing user interfaces are often designed primarily around energy efficiency and comfort management, but still require improvement in terms of perceived affordance for building occupants (Roofigari-Esfahan et al., 2023). These examples indicate that

indoor control interfaces may confuse users and lead to inappropriate or ineffective control behaviors.

However, existing design knowledge and guidelines are still not sufficient to fully address cross-context design and development issues. In related research areas, smart home researchers have increasingly called for a stronger human-centered perspective, but much of the research remains confined to the home environment and often focuses more on user or buyer adoption than on the quality of interaction after adoption (Yao et al., 2023; Yu et al., 2024). Similarly, a systematic review of human-centered IoT found that “human-centered” is often treated more as a label than as an actionable design practice, with limited consensus on its core meaning and with technology-driven approaches still dominating (Ystgaard et al., 2023).

This creates a design gap. What is needed is not only another interface tailored to a single scenario, but a structured approach for identifying which contextual factors drive interaction requirements and how these factors can be translated into design guidance.

Therefore, this thesis investigates the following research question:

Which context of use factors drive interaction requirements for an IoT control unit, and how can these be translated into a control and feedback architecture that suits varying indoor spaces?

In this thesis, the following core terms are used in a specific way:

- *IoT control unit* refers to a control interface used to control connected indoor systems, such as lighting, blinds, temperature, and scenes.
- *Scene* refers to a predefined combination of settings for one or more indoor systems. For example, a scene may adjust several lights, blinds, and temperature settings at the same time to support a specific situation, such as morning use, cleaning, or night mode.
- *Channel* refers to an individually controllable control target or control group in the indoor control system, such as a lighting group, blind group, or a controllable area. Typical channel functions include precise adjustments, such as dimming, brightening, changing blind position, or adjusting another controllable value.
- *Context of use factors* refer to the physical, social, user-related, and task-related conditions that may affect how the control unit is understood and operated.
- *Interaction requirements* refer to what the interface needs to support in order for users to act appropriately, such as modality, feedback, feedforward, control scope, function priority, and task access.
- *Control and feedback architecture* refers to how control functions, displayed information, physical input, feedback, feedforward, user roles, and task hierarchy are organized within the control unit.
- *Push Display* is used in the design case to describe the partner company’s product direction: a local physical control unit with visual labels or display feedback for controlling multiple scenes, channels, or indoor environmental functions.

The thesis investigates how indoor IoT control units can be designed for use across different contexts. The focus is not only on the visual interface or the physical form of a control panel, but on the overall control-and-feedback structure: what the user can control, what information is shown, what feedback is provided, and how the interaction should be when the user, task, and environment are dynamic.

To address this, the project develops a context-to-interaction framework and applies it in the design of a smart indoor control unit in collaboration with an industry partner. The framework is then used as a basis for concept development and concept evaluation.

The thesis is organized as follows:

- **Background** presents the theoretical and literature basis of the work, including context of use, smart control systems, shared indoor spaces, and relevant interaction principles.
- **Methods** explains the overall research approach, user study, design study, concept evaluation, and data analysis.
- **Results** presents the main outcomes from the framework development, user study, design study, and concept evaluation.
- **Design** describes how the framework was constructed and applied in the commercial project.
- **Discussion and Conclusion** reflect on the main findings, limitations, practical implications, and future work.

2

Background

2.1 Indoor IoT Control

Indoor IoT control units are increasingly used to manage connected systems such as lighting, blinds, temperature, and scenes. Compared with a conventional single-purpose switch, this type of control unit often needs to coordinate several devices, support different levels of automation, and show information about the current system state. Therefore, the design problem is not only about designing one interface element. The control unit becomes part of a larger smart environment, where interaction is shaped by the user, the task, the controlled system, and the surrounding context.

This becomes especially important in indoor environment control, since the same type of control unit may be used in very different spatial and social situations.

A control unit in a private room may mainly support personal comfort and direct control. A similar unit in a shared office, hotel lobby, library, or other semi-public environment may involve several users, different permissions, and more visible consequences of action. The controlled objects may still be lighting, blinds, temperature, or scenes, but the interaction requirements can be very different. For this reason, designing across different contexts becomes an important issue for IoT control units.

Human Building Interaction (HBI) provides a useful perspective for this problem. HBI frames the relationship between people and buildings through physical/material, spatial/configurational, and social/cultural dimensions, and positions itself between Human Computer Interaction, architecture, and urban design (Taherkhani & Aziminezhad, 2023). This perspective is relevant because indoor IoT control units are not only technological devices. They also mediate how users interact with buildings and indoor environments. Research on spatial transformation and smart environments also suggests that interactive technologies are increasingly entering both private and shared spaces, which requires stronger connections between interaction design, architecture, and building systems (Çetin Er & Özcan, 2022; Shirehjini & Semsar, 2017).

2.2 Context of Use

A central theoretical basis for this thesis is the concept of context of use. ISO 9241-11 defines usability in relation to specified users, specified goals, and a specified context of use (International Organization for Standardization, 2018). ISO 9241-210 also states that human-centered design should be based on an explicit understanding of users, tasks, and environments (International Organization for Standardization, 2019). In context-aware computing, context is described as information that characterizes a situation relevant to interaction (Dey, 2001). These perspectives show that interaction quality cannot be understood separately from the situation in which interaction takes place.

The Context of Use framework proposed by Maguire (2001) is especially useful here because it organizes context through users, tasks, technical environment, physical environment, and social or organizational environment. This provides a broader structure than spatial classification alone. Instead of only asking where a device is located, it also asks who is using it, what task is being performed, what technology is involved, what physical conditions surround the interaction, and what social or organizational rules may apply.

However, context of use descriptions are often mainly descriptive. They help identify what information may be relevant, but they do not automatically explain how this information should be translated into design requirements. This limitation is important for the present research. A designer may know that a control unit is placed in a semi-public space, that the user is unfamiliar with the system, or that the task is time-sensitive. Still, these facts alone do not directly define the interface structure, feedback style, modality, or control logic. Therefore, the challenge is not only to describe context, but also to understand how context affects interaction.

2.3 Space and Users

One difficulty in designing across contexts is how to define the space itself. Existing spatial taxonomies, such as OmniClass Table 13 *Spaces by Function*, classify spaces according to function or primary use (OmniClass Development Committee, 2012). Similarly, space management documents such as *Space Type Definitions* provide detailed categories of assignable and non-assignable rooms, including classrooms, offices, residential facilities, study spaces, circulation, and infrastructure (Office of Space Planning and Analysis, 2025). These classifications are useful for naming and managing types of spaces, but they do not fully explain the interaction conditions inside those spaces.

For the design of an IoT control unit, a room category alone does not explain who has access, who has authority, whether the action is socially visible, or whether the result affects others. Literature on public and private space therefore becomes relevant. Nissen (2008) argues that public space should not be understood only through ownership, but also through accessibility and usability. The idea of hybrid or semi-public spaces is useful because many contemporary environments exist between

strictly private and strictly public conditions (Nissen, 2008). The Star Model of Publicness also treats publicness as a multidimensional continuum, including ownership, control, civility, physical configuration, and animation (Varna & Tiesdell, 2010). This helps show that spatial context is not only a matter of room type, but also a matter of access, control, and social exposure.

The user side of context is equally important. An IoT control unit used across different contexts may be used by residents, visitors, staff members, facility managers, service personnel, or temporary users. These users may differ in permission, responsibility, familiarity, physical access, and motivation. Accessibility standards are useful here because they frame accessibility in relation to the widest range of user capabilities and the context of use, including users, tasks, equipment, physical environment, and social environment (International Organization for Standardization, 2008b). ISO 9241-171 also emphasizes that barriers can arise not only from permanent impairments, but also from temporary or situational limitations, such as noise, poor lighting, or occupied hands (International Organization for Standardization, 2008a).

Learnability is also relevant because an IoT control unit used across different contexts cannot assume that all users are trained or familiar with the system. Some users may interact with the device every day, while others may encounter it only occasionally or for the first time. Usability literature shows that usability includes several aspects, including performance, satisfaction, and ease of learning, although these aspects are not always treated consistently across standards (Abran et al., 2003). Therefore, learnability is useful for understanding first-time and occasional use, even if it is not enough as a framework variable by itself.

Research on shared smart systems also shows that user type should not be understood only as a demographic category. In smart homes, Geeng and Roesner (2019) distinguish between smart home drivers, who initiate and manage smart devices, and passive users, who are less involved in device decisions. Similarly, Kenderova and Neusesser (2025) distinguish between device managers, everyday users, and restricted users. These role distinctions are relevant because they connect users to control access, responsibility, and decision-making power. Research on controls used by several users also shows the need for flexible and detailed access control in smart home devices, since different users may require different privileges, profiles, and authentication mechanisms (Jang et al., 2017). These studies indicate that user roles can influence what functions users should access, what feedback they need, and how much control the system should expose.

2.4 From Context to Requirements

Spatial and user-focused literature helps describe important context factors, but the next challenge is to translate these factors into interaction requirements. Activity Theory provides one way to approach this issue. Huang and Gartner (2008) argue that context should be understood in relation to activity. Their approach decomposes activity into actions and identifies context parameters relevant to each action. This is useful because it suggests that context should not be collected as an unlimited list.

Instead, a contextual factor becomes relevant when it affects the activity or action that the system is supposed to support.

Environmental analysis offers a more direct connection between context and interaction ability. Ronkainen et al. (2010) argue that environmental characteristics can be analyzed through the restrictions they impose on users, and that these restrictions contribute to the cost of interaction. This perspective shifts the question from what the environment is to what the environment does to the user. For example, illumination can affect visual readability, noise can affect auditory input and output, occupied hands can affect manual input, and temperature can affect tactile sensitivity or dexterity. Research on situational impairments supports the same logic by showing that contextual factors such as ambient light, noise, movement, encumbrance, temperature, and stress can temporarily reduce users' ability to interact with devices (Sarsenbayeva et al., 2017).

Social context also affects interaction. Research on interaction involving several users shows that shared use is influenced by factors such as privacy of space, proximity, familiarity between users, social hierarchy, owner's presence, responsibility, autonomy, and self-efficacy (Shavitt et al., 2021). These factors are relevant because users may technically be able to operate a control unit, but still hesitate if they feel socially exposed, uncertain about permission, or unsure whether they are responsible for the result. Research on device pairing also shows that people do not always choose the fastest or most efficient interaction method. Instead, interaction choices may depend on risk perception, time pressure, social conventions, and the appropriateness of the method in a given situation (Ion et al., 2010). This suggests that social context can influence not only whether users can interact, but also which interaction method feels acceptable.

User interface design patterns provide another bridge between context analysis and design decisions. Javahery et al. (2007) describe how user and context variables can be structured and used as inputs for selecting design patterns. This is relevant because context does not have to lead directly to final interface features. Instead, contextual factors can first be translated into recurring interaction problems or design directions, which can then inform interface structure and behavior. ISO interaction principles and presentation principles also provide useful design vocabulary. ISO 9241-110 includes principles such as suitability for the user's tasks, self-descriptiveness, conformity with user expectations, learnability, controllability, use error robustness, and user engagement (International Organization for Standardization, 2020). ISO 9241-112 provides presentation principles such as detectability, discriminability, unambiguous interpretability, conciseness, and consistency (International Organization for Standardization, 2017).

2.5 Summary

The reviewed literature shows that context is important for the design of IoT control units, but it also reveals a gap. Spatial classifications can identify types of rooms, but they do not explain the interaction conditions inside them. Publicness and HBI provide a broader understanding of space, but they do not directly produce interface

requirements. Accessibility, learnability, and literature on user roles help explain user differences, but they are often more useful for evaluation or user analysis than for generating design guidance. Context of use frameworks provide useful categories, but they remain largely descriptive. Environmental analysis, research on interaction involving several users, and design pattern logic offer stronger ways to connect context to interaction, but none of them alone provides a complete method for designing an indoor IoT control unit across private, semi-public, and public contexts.

Therefore, a framework for translating context into interaction requirements is needed. Such a framework could identify relevant contextual factors, interpret what these factors affect in interaction, and connect them to design guidance for control, feedback, modality, information structure, and function prioritization.

3

Methods

This chapter explains how the project was carried out. The project combined framework development based on literature, a user study, a design study based on a real case, and comparative concept evaluation. The aim was not only to design an indoor IoT control unit, but also to understand how context of use factors can be translated into interaction requirements and design guidance.

The work was organized into four main phases. First, a literature review was used to build a preliminary framework for translating context into interaction requirements. Then, a user study was conducted to collect user needs and to ground the framework in real and scenario-based situations. After that, a design study was carried out in collaboration with an industry partner, where the framework was applied to smart control unit concepts. Finally, the concepts were evaluated through usability measures in different scenarios.

3.1 Framework Development

The first phase focused on developing the framework from the literature. This phase aimed to identify contextual factors that may influence interaction with indoor IoT control units. The review focused on two main areas: indoor smart control systems and smart environments, and context-related research such as accessibility, user roles, interaction involving multiple users, and translation from context to interaction requirements.

Relevant concepts and factors were extracted from the literature and compared according to their usefulness for design across different contexts. The aim was to build one that could support the design of an IoT control unit across different indoor contexts.

3.2 User Study

After the preliminary framework had been developed, a user study was conducted as the starting point for the product design phase. This study had two main aims: to collect detailed user needs related to smart indoor control, and to examine whether the framework could help structure and explain user behavior in real and scenario-based situations.

The user study included four parts: a survey, field studies, long interviews, and scenario enactments with group discussion. These methods were combined to cover different levels of context, from private home use to shared and public environments.

The survey collected broader information about people's experiences with smart control systems in and outside home environments. The questions focused on previous experience, control methods, common tasks, preferences, and perceived difficulties.

Field studies were conducted in spaces with different degrees of publicness, including campus study areas, shared offices, hotel lobbies, and libraries. These studies focused on how control points appeared in real spaces, whether they were visible or hidden, who seemed to have access to them, and whether people actually interacted with them. Short informal interviews were used when possible to clarify observed behavior or to understand how users interpreted the control situation.

The long interviews focused mainly on private smart home use. Four semi-structured interviews were conducted with participants who had different levels of experience with smart home systems. The interviews covered living situation, smart systems used, setup and maintenance responsibility, common control tasks, positive and negative incidents, preferred interaction methods, control permissions, and reactions to existing interface examples. Critical incidents and cognitive walkthrough style questions were used to understand what participants actually did, what they expected to happen, and what feedback made them trust or distrust the system.

Scenario enactments were used to explore social issues and issues related to user roles in more detail. Participants were placed into scenario roles in home and office environments and discussed how they would act in different situations involving smart environmental controls. These scenarios helped explore role expectations, authority, social exposure, responsibility, control permission, trust, and interaction tone. The enactments were followed by open discussion about existing interface examples, grounded in the social and contextual issues raised during the scenarios.

Together, these methods provided material for understanding how users interpret smart control in different contexts. The focus was not only on whether an interface was easy to use, but also on whether users felt allowed to use it, whether they understood the scope of control, whether the result would affect others, and whether the interaction felt safe, recoverable, and socially appropriate.

3.3 Design Study

The design study was conducted in collaboration with an industry partner. In this phase, the framework was used as a design support tool for developing smart indoor control unit concepts. The business case provided a practical context for testing whether the framework could be used in a real design process.

Two design directions were developed. The first was a concept mainly driven by the framework. This direction explored what kind of control and feedback architecture could be produced when contextual factors were used as the main design driver.

The second was a concept informed by business considerations. This direction combined the framework with input from the commercial design context, including competitor analysis, business considerations, partner insights, product requirements, size constraints, cost considerations, and expected market fit. This allowed the project to examine how the framework could work together with practical product development constraints.

The two concepts therefore represented different design logic. One prioritized support across different contexts, while the other prioritized commercial feasibility. Both concepts were developed into prototypes for evaluation.

3.4 Concept Evaluation

The final phase was a comparative concept evaluation. It examined how the two concepts performed across different contexts, roles, and task goals. The aim was to understand the strengths and limitations of each design logic.

Evaluation scenarios were selected through the framework. Five candidate scenarios were first analyzed: hotel room, hotel lobby, office lobby, personal office, and restaurant. Each scenario was examined according to physical context, social context, user roles, and task levels. This helped identify the interaction tendency of each scenario and the type of design support it required, such as professional feedback, professional efficiency, personalization, or personalized efficiency.

Since each evaluation session involved scenario introduction, feature importance rating, prototype task completion, experience rating, and repeated tasks across scenarios, testing all five scenarios was not feasible within the available time. Therefore, the hotel room and hotel lobby were selected. These two contexts represented the widest contrast among the analyzed scenarios. The hotel room represented a more private context with low social exposure and many first-time users, while the hotel lobby represented a more visible, shared, role-defined, and operational context. Together, they gave broader coverage of the framework than two similar contexts would have done.

The same framework analysis was also used to decide which evaluation variables were relevant for this design case. Based on the contextual demands identified in the selected scenarios, the evaluation focused on understanding time, task performance, single-handed operation, perceived ease of use, perceived trust, functionality, and overall experience.

Two concepts were evaluated through testing in scenarios. The hotel room scenarios included the roles of guest and cleaner. The hotel lobby scenarios included the roles of cleaner and front desk staff. These role changes were included to observe whether each concept could remain understandable and usable when the user role, task goal, and control responsibility changed.

Eight participants took part in the concept evaluation. Some participants tested both concepts, while others tested one concept. Each evaluation followed four main steps. First, participants were presented with a scenario and asked to evaluate how

much they cared about different device features in that situation. Second, they used the prototype to complete the given task goal. Third, they rated their experience. Finally, the process was repeated across different scenarios so that role changes, context changes, goal changes, and learning effects could be observed.

The evaluation collected data related to task performance and learning curves. The prototypes and evaluation forms were presented on an iPad, while scenario images were shown separately to support the scenario setting. As shown in Figure 3.1, the scenario picture was displayed on a separate screen, while the prototype and evaluation forms were completed on an iPad. This setup allowed participants to keep the scenario context visible while interacting with the concept prototype and scoring the evaluation sheets.

The evaluation process shown in Figure 3.1 consisted of four steps:

- **Step 1: Scenario-based attribute importance rating.** Participants first reviewed the scenario and rated how important different product or interaction attributes were in that specific situation.
- **Step 2: Prototype task completion.** Participants then used the interactive prototype to complete the given task in the scenario.
- **Step 3: Experience rating.** After completing the task, participants rated their experience using the scaled objective feedback sheet.
- **Step 4: Repetition across scenarios.** The same process was repeated across different scenarios and concepts in order to observe changes in understanding, task performance, and learning over time.

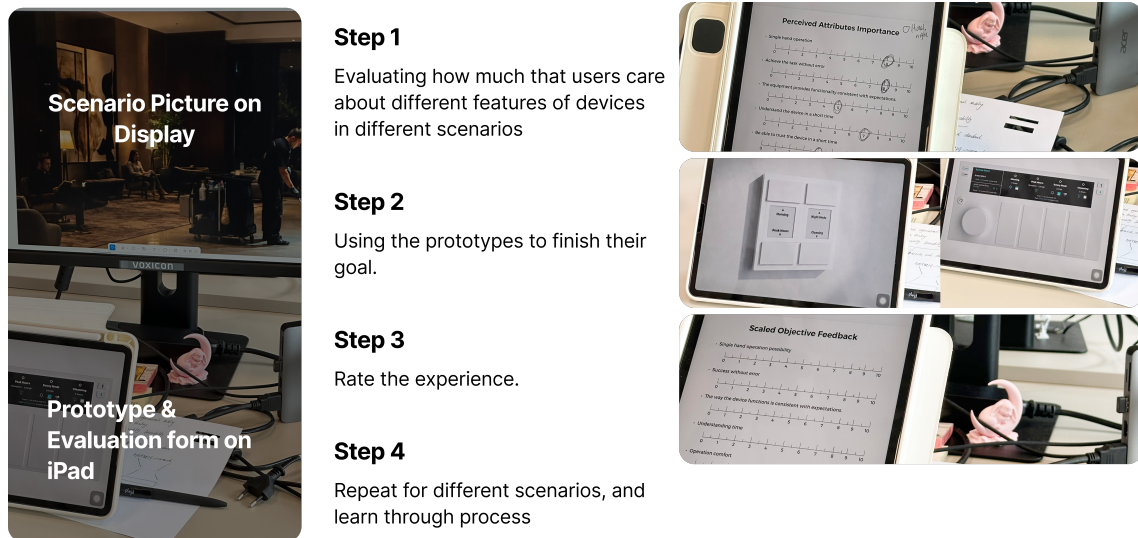


Figure 3.1: Evaluation setup with scenario display, iPad prototype, and evaluation forms

The interactive prototypes were built in Origami Studio and presented as iPad-based prototypes. In this thesis, an *Origami prototype* refers to an interactive digital prototype created with Origami Studio, a prototyping software originally developed

inside Facebook and now provided by Meta for designing, animating, and testing interactive interface behaviors. In this project, the software was used to simulate the basic interaction logic of the concepts. As shown in Figure 3.2, the left side of the screenshot shows the component and layer structure of the prototype, the central artboard shows the interface layout that participants interacted with, and the lower part shows the node-based interaction logic used to connect user actions with interface responses.

The prototype included page switching, mode selection, scene or area selection, and feedback states. Page switching allowed participants to move between different interface pages when more scenes, areas, or functions were available than could be shown on one page. Mode selection allowed participants to switch between different control modes, such as scene selection and area selection. Scene or area selection allowed participants to activate a predefined scene or choose a specific area as the active control target. Feedback states showed basic system responses, such as whether an item was selected, whether an action was being processed, or whether the action had been completed. This allowed the evaluation to test not only the visual layout of the concepts, but also the basic interaction logic, including changing pages, selecting control targets, activating scenes, and observing feedback.

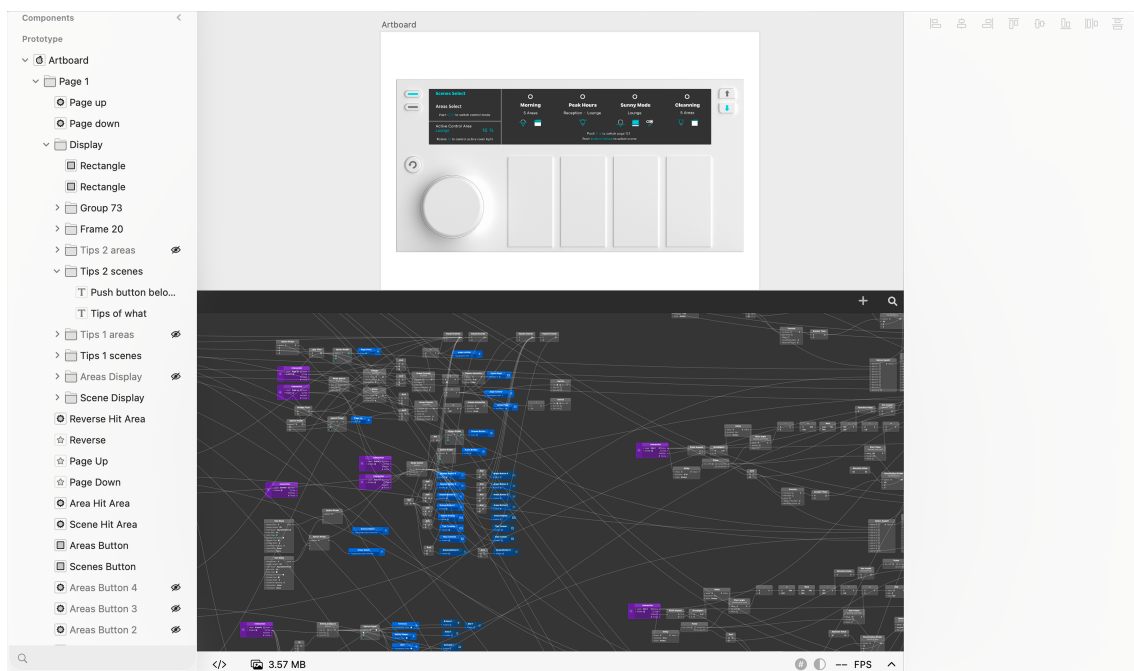


Figure 3.2: Origami prototype used for the concept evaluation

3.5 Data Analysis

Data analysis combined qualitative thematic analysis and quantitative comparison. User study data were analyzed qualitatively by grouping survey responses, field observations, interview material, and scenario enactment notes into recurring themes. The main analysis categories were roles and authority by setting, task families,

control granularity preference, legibility and mapping, unknown system handling, feedback and trust, social exposure and accountability, and learning or onboarding across encounters.

This qualitative analysis was used to identify points of convergence and divergence between the framework based mainly on literature and the user study material. Themes that appeared across several methods were treated as stronger design considerations. Themes that appeared only in specific contexts were treated as context-dependent rather than universal. These findings were then used to refine the framework and inform concept development.

Concept evaluation data were analyzed through scenario scores, learning patterns, index comparison, and comparison between the two concepts. Understanding time and task performance were used to examine whether participants could understand and complete the task efficiently. Single-handed operation was used to examine whether the concepts supported situations where one hand might be occupied. Perceived ease of use, perceived trust, functionality, and overall experience were used to compare the perceived quality and suitability of the two concepts across the selected scenarios.

The results of the user study, business input, and concept evaluation are presented in the Results chapter. The Design chapter then explains how the framework and the evaluation findings informed the final design direction.

4

Results

This chapter presents the results of framework development, user research, commercial implementation, and concept evaluation. It aims to report the research findings that inform the design work. Detailed framework and design concepts will be presented in the Design chapter.

4.1 Framework Outcome

The framework development resulted in a framework for analyzing context factors and translating them into interaction design guidance. The aim of the framework is to support the design process by showing how different context factors may affect control, feedback, modality, interaction method, information structure, and function priority.

Figure 4.1 gives an overview of the framework structure. The upper part of the figure shows the general translation logic used in the framework: a contextual factor is first identified, then interpreted through what it affects in interaction, and finally connected to design guidance. This means that the framework does not move directly from context to interface features. Instead, it introduces an intermediate layer between the context and the design guideline.

The lower part of Figure 4.1 shows how this translation logic is applied through three parts of the framework: social factors, physical factors, and user and task factors. The social part starts from environmental social factors and translates them into decision-making impacts, including the user's sense of responsibility, autonomy, and self-efficacy. These impacts then support design guidance related to interaction method, feedback, feedforward, and interaction style. The physical part starts from environmental physical factors and translates them into ability impacts, including visual output, tactile output, audio input and output, and manual input. These impacts then support decisions about suitable interaction modalities and accessibility-related design suggestions. The user and task part starts from the user role and connects it to task analysis and task hierarchy. This part supports decisions about preferred functions, function priority, task access, and local control depth. Together, these three parts allow the framework to connect environmental conditions, social decision-making, and user task needs to interaction design guidance.

In this way, the framework can be used in design projects that involve several possible contexts. Designers can first define typical scenarios, then analyze each scenario

through the three parts of the framework. The result of this analysis is a set of design directions, such as preferred modality, preferred interaction method, required feedback level, control hierarchy, and function priority. The detailed evaluation sheets used for physical factors, social factors, and user and task factors are presented in Appendix A.

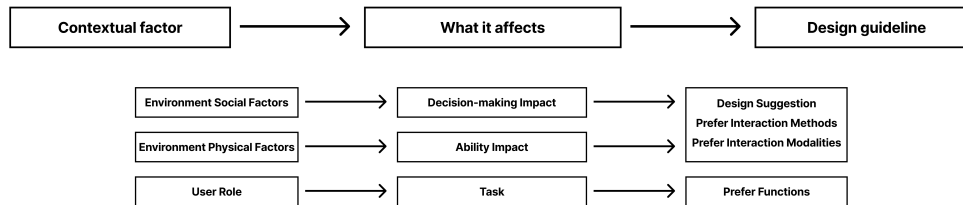


Figure 4.1: Overview of the framework for translating context factors into interaction design guidance

4.2 User Study Results

The user study produced two main outcomes. First, it provided user needs for the later design work. Second, it helped ground and refine the framework developed from the literature. Across the survey, field studies, interviews, and scenario enactments, the findings showed that smart control is not only a question of whether users can operate an interface. It is also affected by whether users understand what they are controlling, whether they feel allowed to act, whether the result may affect others, and whether the system response can be trusted.

A clear need was found for visible and understandable control scope. Users needed to know what the control unit affected before acting, especially in shared or public spaces. When the affected area or device was unclear, users became less willing to interact, even when the control was physically available. This supported the framework’s focus on social factors and user task factors, because control decisions were shaped not only by usability, but also by perceived responsibility and uncertainty about consequences.

Feedback and recovery also appeared as important user needs. Participants wanted clear confirmation that the system had received their action and that the expected change had actually happened. Direct visual change, tactile confirmation, visible status, and physical fallback were often more trusted than hidden system responses. This supported the physical part of the framework, especially the translation from environmental conditions to suitable modalities and feedback forms. It also showed that feedback should not only confirm an input, but also help users recover when the result is delayed, unclear, or wrong.

The findings also supported the importance of user roles. The same control unit could involve device managers, everyday users, restricted users, guests, staff, or temporary users. These roles were not only defined by technical access, but also by

social permission, responsibility, and familiarity with the space. For this reason, user roles need to be considered together with task level. Frequent and simple actions, such as turning lights on or off, changing brightness, or selecting predefined settings, should be easy to access. More complex actions, such as changing scenes, managing device hierarchy, or maintenance-related tasks, should be placed deeper or limited to users with higher responsibility.

The user study also showed that unfamiliar systems are rarely explored freely. In shared contexts, users often hesitated because they did not know whether they were the right person to act, whether others would be affected, or whether a mistake would be visible. This finding strengthened the social part of the framework. Risk, hierarchy, time pressure, and social exposure all affected how confident users felt during interaction. A suitable control interface therefore needs to support safe exploration, clear permission cues, predictable results, and low-consequence interaction for less experienced users.

Overall, the user study supported the main structure of the framework. Physical factors affected how users could perceive and operate the control unit. Social factors affected willingness, confidence, and perceived permission to act. User and task factors affected which functions should be visible, simplified, protected, or placed in deeper layers.

4.3 Design Study Results

The design study resulted in two smart control unit concepts. These two concepts were not developed only as different visual alternatives, but as two different ways of approaching the same design problem.

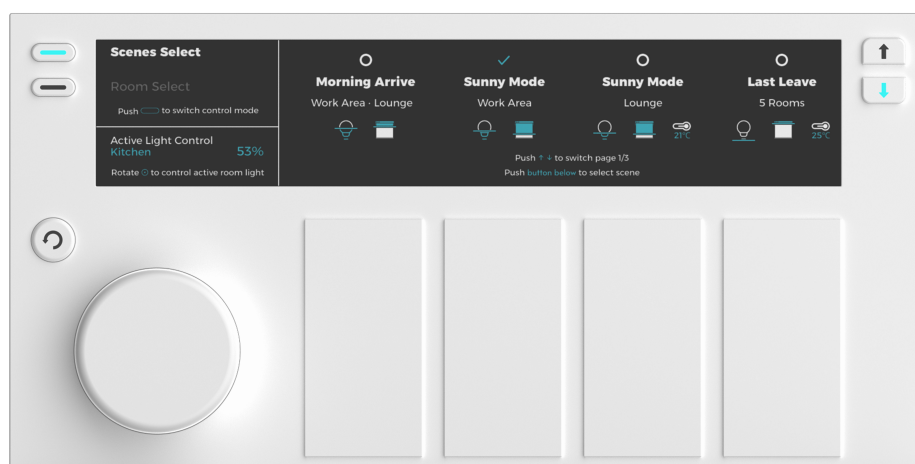


Figure 4.2: Concept 1, developed mainly from the framework

Figure 4.2 shows Concept 1. The concept combines physical controls with a larger visual information area, so that the user can see labels, control state, and feedback while still using physical input. The figure also shows that Concept 1 was intended to support a broader control structure, including both scene control and more detailed control of devices or areas.

Concept 1 was mainly developed from the framework. The design started from the selected contexts and translated the physical, social, user, and task factors into control structure, feedback, modality, and function priority. As a result, this concept placed more emphasis on supporting different users, different task levels, and changes between contexts. It provided a broader control structure and a clearer separation between scene control and more detailed device control. This made the concept more complex, but also gave it stronger potential to support use across different contexts.

Figure 4.3 shows Concept 2. Compared with Concept 1, this concept uses a more compact layout with fewer visible functions. The figure illustrates how Concept 2 combines direct physical button interaction with readable labels, aiming to make the product easier to understand at first time use and more feasible as a commercial local control unit.



Figure 4.3: Concept 2, developed with stronger commercial and market considerations

Concept 2 was developed with stronger consideration of commercial and market-related factors. This concept still used the framework as a background reference, but the design decisions were also shaped by competitor analysis, partner input, product size, expected cost, ease of understanding, and market fit. Compared with Concept 1, it became more compact and easier to approach at first time use. However, it also had to simplify some of the control structure, which reduced how much complexity it could support across different roles and contexts.

The design study therefore suggested that the framework was useful as a way to structure the design process. It helped identify what kinds of control, feedback, modality, and function levels should be considered when the same control unit may be used in different contexts. In particular, the concept developed mainly from the framework showed stronger potential for supporting variation between contexts, which indicates that the framework can provide useful design direction.

At the same time, the design study also showed that the framework alone is not enough for a commercial design project. When the concept was developed closer to a real product direction, additional factors became important, including size, cost, manufacturing feasibility, competitor positioning, partner expectations, and how quickly users could understand the product. Therefore, the result of the design study was not only a design concept, but also an understanding of the trade-off between systematic support across contexts and practical commercial feasibility.

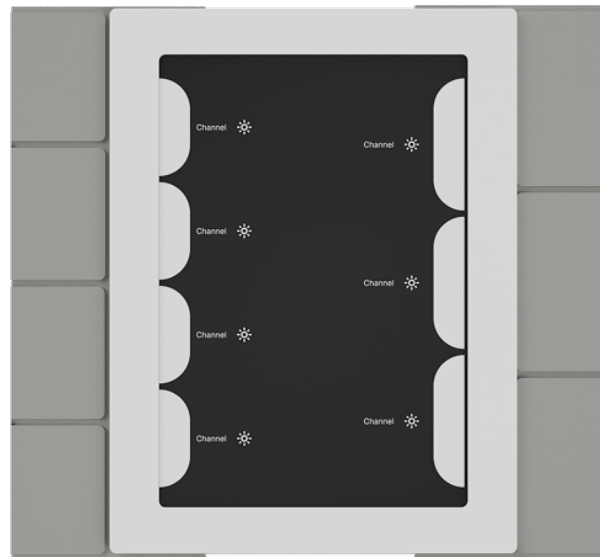


Figure 4.4: Flexible button concept for handling different numbers of active buttons

In addition to the two main concepts, the design study also produced an additional physical product idea: the flexible button concept. This concept was not included as one of the two main evaluated concepts, because it was less directly connected to the framework comparison. Instead, it emerged from the commercial side of the project, especially the need to handle the problem of unused or “dead” buttons when the number of physical buttons does not match the number of active scenes or functions.

Figure 4.4 shows the main idea of the flexible button concept. The concept explores a physical button surface that can support different numbers of visible control areas, depending on how many scenes, channels, or functions are active in a specific installation.

The flexible button concept explored whether the number of available buttons could be changed physically. Instead of fixing one button layout for all installations, the product could support different button counts by using a reversible or reconfigurable button surface. In this way, the same product could adapt to different numbers of scenes or control targets without leaving inactive buttons visible to the user.

This idea was not developed as far as the two main interface concepts, but it became an important side result of the design study. Therefore, the flexible button concept was treated as an unexpected but relevant design outcome, rather than as a core concept for evaluation.

4.4 Concept Evaluation Results

The concept evaluation provided a comparison between the two design directions and helped examine how the framework worked when applied to concrete design concepts. Instead of showing one concept as clearly better than the other, the results showed a trade-off between immediate understanding and stability across different contexts.

Concept 2 was generally easier for participants to understand at first. Its simpler structure and more compact interaction made it more approachable, especially when the task was direct and the scenario matched the interface logic. This result showed the value of commercial and market-related considerations, such as product size, simplicity, and first impression. These factors are important when a concept needs to be understandable without much explanation.

Concept 1 required more initial understanding. Participants needed more time to understand the structure and the relation between scene control and more detailed device control. However, after users understood the logic, the concept showed better stability when the role, context, or task goal changed. This suggests that the framework helped the design cover a wider range of use situations. In this sense, the evaluation gave some support to the usefulness of the framework, especially for design problems where the same control unit needs to work across different environments and user roles.

At the same time, the evaluation also showed a limitation of using the framework directly. Because the framework asks designers to consider physical factors, social factors, user roles, task levels, feedback, modality, and control hierarchy, it may lead to a concept with a more complex system structure. This complexity can be useful for supporting different contexts, but it can also increase the learning burden for users and make the product harder to communicate at first time use.

Therefore, there is a design tension in applying the framework to a commercial project. A concept based strongly on the framework may support context variation better, but it may also require more careful simplification before becoming a practical product. A concept shaped more strongly by commercial considerations may be easier to understand and more feasible as a product, but may lose some flexibility when the context, role, or task changes.

Overall, the evaluation suggests that the framework can be useful for identifying and translating contextual requirements into design decisions. However, its application

needs to be balanced with simplicity, product feasibility, and user learning-effort. For a commercial smart control unit, the framework should therefore be used as a design support tool, rather than as a direct recipe for the final interface.

4.5 Data Analysis Results

The data analysis helped connect the user study, framework development, and concept evaluation. The qualitative analysis of the user study material produced a clearer set of user needs, while the quantitative analysis of the concept evaluation helped compare how the two concepts performed across the selected scenarios.

The qualitative analysis grouped findings from the survey, field studies, interviews, and scenario enactments into recurring themes. These themes included role and authority, task families, control granularity, legibility and mapping, unknown system handling, feedback and trust, social exposure, and learning across repeated encounters. This analysis helped clarify which needs appeared across different methods and which needs were more dependent on specific contexts.

The quantitative analysis was mainly used to compare the two concepts in the evaluation. Scenario scores, understanding time, task performance, single-handed operation, perceived ease of use, perceived trust, functionality, and overall experience were compared across the hotel room and hotel lobby scenarios. This made it possible to identify not only which concept performed better in a specific scenario, but also how stable each concept was when the user role, context, or task goal changed.

In summary, the qualitative and quantitative analysis supported the project in two ways. First, the qualitative analysis helped turn user study material into design requirements. Second, the quantitative analysis helped evaluate the design consequences of two different design logics. The analysis therefore provided a bridge between research findings and design decisions.

The evaluation tables, charts, and comparison data are included in Appendix B. Summarized versions of the user study transcripts and supporting materials are included in Appendix C.

5

Design

This chapter presents the design part of the project. It includes three main sections. The first section explains the design of the framework, including how context factors were organized and translated into interaction design guidance. The second section explains how the framework can be implemented in design projects more generally, including the main application steps and a simple example. The third section presents the commercial project design study, where the framework was applied together with market, business, and partner-related considerations.

5.1 Framework Design

Before the final framework was formed, an initial framework was first developed based on the earlier literature review and exploratory work. This initial framework was important because it helped organize the broad and vague idea of context into more concrete variables. At that stage, the framework mainly included publicness, user roles, frequency of use, and user experience.

5.1.1 Initial Framework

The framework produced during the initial exploration phase is shown in Figure 5.1. The value of this framework was that it allowed the exploratory data to be organized into a more systematic structure. Before this point, context was still understood mainly as the background conditions in which users operate. The initial framework divided it into separate components. Publicness described the nature of the environment. User roles and frequency of use described the characteristics of the people who may use the control unit and their level of interaction. Experience was introduced to specify the level of expertise of the focus user. In other words, the initial framework helped move the discussion from a general idea of context toward more concrete parameters.

The initial framework also had a practical advantage. It allowed the designer to ask more concrete questions about a particular context. For example, a space could be assessed in terms of whether it was public, semi-public, or private. The designer could also ask which user groups would interact with the control unit, who should be considered the primary or secondary user, and whether the focus user was expected to be a novice, normal user, or experienced user. This was important because it made it difficult to assume one universal user for a smart control interface. It also

showed that the same control unit may require different design solutions depending on the target users and their experience levels.

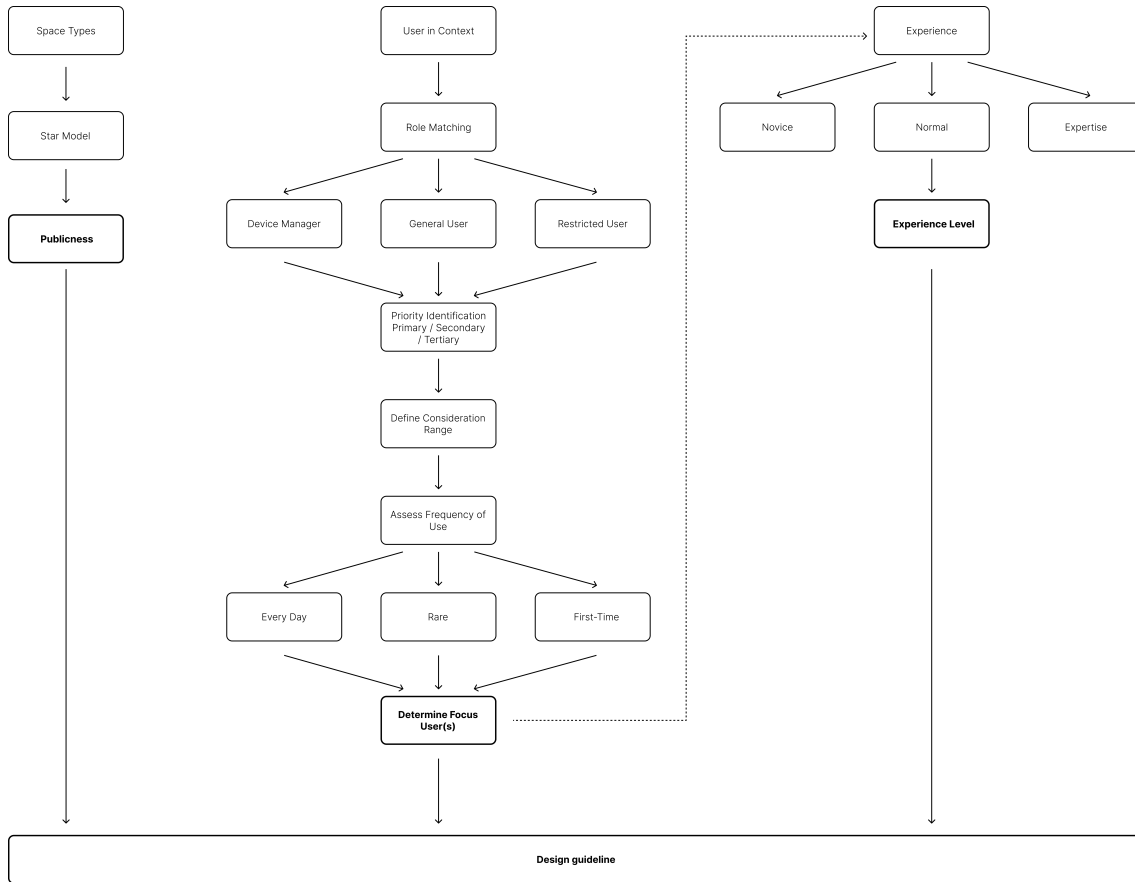


Figure 5.1: Initial framework

However, the initial framework also revealed a major problem. While the identified variables helped describe the use context, they did not clearly explain how to create design guidance from that context. For user variables, the path toward design was relatively easier to imagine. If the focus user is a novice or first-time user, the designer may expect a stronger need for guidance, feedback, and lower learning-effort. If the focus user is experienced, the design may need quicker access and more efficient interaction. In this sense, user roles, frequency of use, and experience level could still support interface development.

The spatial variable was more difficult to use. Publicness could describe whether a space was public, semi-public, or private, but it did not directly explain what should be designed. Even if an office lobby was assessed as a semi-public space, this did not clearly indicate the required type of control, feedback style, information density, or permission logic. The relation between publicness and design decisions was still indirect. Publicness helped describe the environment, but it did not provide enough actionable guidance for design.

Another limitation was that the main components of the initial framework were not sufficiently connected to each other. Publicness, user roles, frequency of use, and

experience level could all help describe the context, but they did not explain how the combination of these variables should affect design. For example, the framework could show that a situation involved a semi-public space, a general user, and a low experience level, but it did not explain how these aspects should be translated into control structure, modality, feedback, or function priority. Overall, the initial framework was more useful as a descriptive tool than as a design tool.

For this reason, the next step was to reform the framework from a descriptive model into a translation model. The final framework still started from context factors, but it no longer stopped at naming or classifying them. Instead, it asked what each factor affects in interaction, and how this effect can be connected to design guidance.

5.1.2 Framework Formation

The formation of the final framework was based on the gap identified through the initial framework, the literature review, and the user study. These parts of the project all showed that context factors are important for indoor IoT control units, but context descriptions alone are not enough for design. For example, knowing that a device is used in a shared space, by an unfamiliar user, or under time pressure does not directly tell the designer what kind of feedback, modality, control structure, or function priority should be used.

Therefore, the framework was organized as a translation structure. It does not move directly from context to interface. Instead, it uses an intermediate layer between context analysis and design guidance. This intermediate layer describes what the context factor affects in interaction.

The structure was partly based on broad context of use constructs, such as the ones described by Maguire (2001). However, the framework reorganized these contextual elements according to their design meaning. Physical environment factors were interpreted through their impact on user ability and suitable interaction modality. Environmental social factors were interpreted through their impact on responsibility, autonomy, self-efficacy, control permission, and social exposure. User roles were connected to task access, control scope, and the functions that different users may need to perform.

ISO interaction principles and accessibility standards were then used as one way to connect these interaction effects to design guidance. ISO 9241-110 provides principles such as suitability for the user's tasks, self-descriptiveness, conformity with user expectations, controllability, use error robustness, learnability, and user engagement (International Organization for Standardization, 2020). ISO 9241-112 provides presentation principles such as detectability, discriminability, unambiguous interpretability, conciseness, and consistency (International Organization for Standardization, 2017). These principles did not define the context factors themselves, but they helped provide a vocabulary for converting interaction effects into design requirements.

Based on these considerations, the framework was organized around three elements: contextual factor, what it affects, and design guideline. As shown in Figure 4.1 in the previous chapter, the framework distinguishes between different contextual

sources and traces how they influence interaction before arriving at design implications. Environmental social factors are connected to decision-making impact, environmental physical factors are connected to ability impact, and user role is connected to task-related implications. These intermediate layers then inform design suggestions, preferred interaction methods, preferred interaction modalities, and preferred functions.

5.1.2.1 Environmental Physical Factors

The first environmental aspect was *environmental physical factors*. The initial definition of this category followed the environmental analysis concept suggested by Ronkainen et al. (2010). Although their work was originally formulated for multimodal and multidevice interfaces, especially mobile device interactions, it was relevant to this study because it treated the physical environment as a set of conditions that can directly influence the user's interaction ability. In other words, the physical environment was not considered only as background information, but as a source of constraints that may affect whether users can see, hear, feel, reach, and operate the interface.

However, the original list of environmental factors could not be fully adopted. Since the article was written in the context of mobile device interaction, some factors were either eliminated or redefined to make them more suitable for an indoor IoT control unit, including both units mounted on walls and fixed units used as part of an indoor environment control system. Repeated factors that affected similar abilities were also merged in order to keep the list concise and applicable across different indoor contexts.

As a result, the retained factors were classified according to the type of sensory or motor ability they may affect. Visual factors relate to the user's ability to see, read, and understand information on the screen. Tactile factors refer to the user's ability to perceive touch, vibration, or haptic feedback. Auditory factors refer to the ability to perceive and interpret auditory information, such as alarms, speech, or feedback sounds. Reach and dexterity factors relate to the user's ability to physically reach and operate the control device. A summary of the selected environmental physical factors is given in Table 5.1.

Table 5.1: Environmental physical factors for the framework

Factor group	Selected factor	Meaning
Visual factors	Illumination	Lighting conditions that may influence the user's ability to see and read the displayed information.
Visual factors	Weather	Interference caused by weather conditions or similar external factors that impair visibility, especially in transitional zones.

Factor group	Selected factor	Meaning
Visual factors	Typical installation place	The common location of the control unit, such as mounted on a wall, placed on a desk, or located near a functional zone.
Visual factors	Typical viewing distance and angle	Viewing conditions that influence text size, icon size, contrast, and overall interface legibility.
Visual factors	Continuous visual attention	Situations where the user needs to spend a considerable amount of time observing the interface.
Visual factors	Availability of eyesight	Whether the interaction can rely mainly on visual information.
Tactile factors	Typical contact location	Physical conditions for receiving tactile output or physical feedback from the control device.
Tactile factors	Vibration interference	Situations where vibration signals from the device may be confused with vibration from another source.
Tactile factors	Temperature	Low temperature may reduce the ability to receive haptic feedback or perform interaction-based on touch.
Tactile factors	Gloves or covered hands	Gloves or covered hands may reduce touch sensitivity and the ability to operate the device.
Auditory factors	Background noise level and spectrum	Noise that affects the user's ability to hear alarms, speech, or auditory feedback.
Auditory factors	Babble noise	Human speech that may cause distraction or interfere with speech input and output.
Auditory factors	Sporadic noise	Irregular noises that may interfere with the user's ability to notice or interpret device sounds.
Auditory factors	Blocked ears	Conditions where headphones, clothing, or protective equipment prevent the user from hearing device sounds.
Auditory factors	Need to listen to the environment	Situations where the user needs to remain attentive to ambient sounds, making auditory notifications potentially distracting or inappropriate.
Reach and dexterity	Device location	The physical location of the device, which affects ease of access and operation.

Factor group	Selected factor	Meaning
Reach and dexterity	Number of hands available	Whether the user can use both hands, one hand, or no free hand to interact with the control unit.
Reach and dexterity	Available manual space	The available space for physical interaction, such as pressing, turning, sliding, or reaching.
Reach and dexterity	Need for visual guidance	Whether the user needs to look at the device while operating it manually.
Reach and dexterity	Gloves or hand covering	Gloves or hand covering that may hinder pressing, gripping, or fine adjustment.
Reach and dexterity	Wet or slippery conditions	Rain, snow, or wet hands that may make the device surface slippery and harder to operate.
Reach and dexterity	Temperature	Low temperature that may reduce comfort, speed, or precision during manual interaction.

These factors formed the physical environment side of the framework. They did not directly prescribe interface features. Instead, they described physical conditions that may influence the user's sensory and motor abilities during interaction. Therefore, the next step was to translate them into *ability impact*.

5.1.2.2 Ability Impact

After identifying the environmental physical factors, the next step was to translate them into *ability impacts*. This layer was introduced to make the physical factors more human-centered. Instead of treating factors such as illumination, noise, temperature, or device location as isolated environmental descriptions, the framework asks what kind of interaction ability they affect.

Based on the categories discussed by Ronkainen et al. (2010), four ability impacts were selected for this framework: visual output, tactile output, audio input and output, and manual input. The selected ability impacts are presented in Table 5.2. In the framework, they function as the intermediate layer between environmental physical factors and design guidance. They clarify whether a contextual condition primarily affects visibility, tactile perception, auditory communication, or manual operation.

Table 5.2: Ability impacts for the framework

Ability impact	Meaning
Visual output	The user’s ability to see, read, and understand text, graphics, icons, light signals, and system states on the control unit or display. This also includes the ability to notice dynamic changes in visual information when they appear.
Tactile output	The user’s ability to feel and interpret physical or tactile feedback from the control unit. This ability may be affected when tactile output is masked by environmental factors, confused with other vibrations, or perceived as disturbing in a specific context.
Audio input and output	The user’s ability to speak in the environment, the device’s ability to recognize voice commands, and the user’s ability to hear and understand device output, including speech and non-speech audio.
Manual input	The user’s ability to use one or both hands to operate the control unit, adjust it accurately, access it quickly, and locate the controls that need to be pressed or manipulated.

This translation made the physical component of the framework more actionable. Poor illumination, for example, was no longer treated only as a characteristic of the environment, but as a possible limitation of visual output. Background noise could be understood as a limitation of audio input and output.

5.1.2.3 Design Suggestion: Environmental Physical Factors

After the ability impacts were defined, the next step was to connect them with possible design suggestions. At this stage, the aim was not to produce a fixed interface solution, but to identify where designers should look for relevant guidance when a certain ability is affected. Therefore, this part of the framework worked as a reference layer between ability impact and later design decisions.

The design suggestions were mainly organized according to the same ability categories used in the previous step. For visual output, hearing, and reach and dexterity, the Inclusive Design Toolkit was used as the main reference source because it provides design guidance based on different capability areas, such as vision, hearing, and reach and dexterity (Inclusive Design Toolkit, 2026). For tactile output, ISO 9241-20 was used as the main reference because it includes user needs related to tactile alternatives, tactile indicators, non-visual feedback, and alternatives to tactile output (International Organization for Standardization, 2008b). The framework did not reproduce all detailed recommendations from these sources. Instead, it mapped each ability impact to the corresponding design suggestion area, as summarized in Table 5.3.

Table 5.3: Design suggestion sources for ability impacts

Ability impact	Design suggestion areas	Main reference source
Visual output	Size and shape of visual elements; contrast; color; lighting and glare; layout.	Inclusive Design Toolkit: Vision guidance.
Tactile output	Tactile alternatives; tactile indicators; non-visual feedback; visual or auditory alternatives to tactile feedback; sufficiently distinguishable tactile cues.	ISO 9241-20:2008 tactile related user needs and recommendations.
Audio input and output	Volume of sounds; pitch and clarity; location of sounds; use of speech; background noise and reverberation; population statistics-related to hearing.	Inclusive Design Toolkit: Hearing guidance.
Manual input	Positioning of controls; product flexibility; suitability for the task; ease of gripping; contact area; precision requirements; force requirements; environmental context; population statistics related to reach and dexterity.	Inclusive Design Toolkit: Reach and Dexterity guidance.

They served as triggers for selecting relevant design guidance. For example, if a context reduced visual output ability, the designer should examine guidance related to visual size, contrast, color, lighting, glare, and layout. If a context reduced manual input ability, the designer should examine guidance related to control placement, gripping, force requirements, precision, and available physical space. This made the framework more actionable while still keeping the design suggestions open enough to be adapted to different contexts.

5.1.2.4 Environmental Social Factors

The next environmental aspect of the framework was *environmental social factors*. Compared to physical factors, social factors were harder to define as they did not refer directly to whether the user was able to interact with the control unit visually, auditorily, or physically. Instead, social factors defined the environment in which the interaction happened, including whether other people were present, whether the user was allowed to perform the action, whether this action may disturb other users, and whether the result of the action may influence a larger group of users.

Based on the decision logic proposed by Ion et al. (2010), the structure of the environmental social factors was formulated. Even though this research focused on decisions in device pairing processes, it was important since it showed that interaction methods do not always rely on efficiency; sometimes decisions are made based on

risk perception, interaction urgency, social considerations, and appropriateness of actions in specific situations (Ion et al., 2010). The present research also implied social factors as one of its main considerations, since the use of an indoor control unit may raise similar issues. For example, a user may find that an indoor control device is easy to interact with technically. However, he or she may not feel comfortable if this happens in front of other people, if there is uncertainty regarding the control hierarchy in this situation, or if the result of action influences multiple people.

Figure 5.2 illustrates how the decision logic from the device pairing process was adopted as a tool to group social factors. Specifically, the original figure describes how the decision to choose a specific device pairing method was influenced by several contextual considerations such as data sensitivity, place safety, time pressure, the presence of other people around, and the relationship between the users involved in the decision-making process. None of these aspects were taken as direct rules for developing interaction with an indoor IoT control unit. Instead, these factors were generalized as broader concepts influencing the decision-making process.

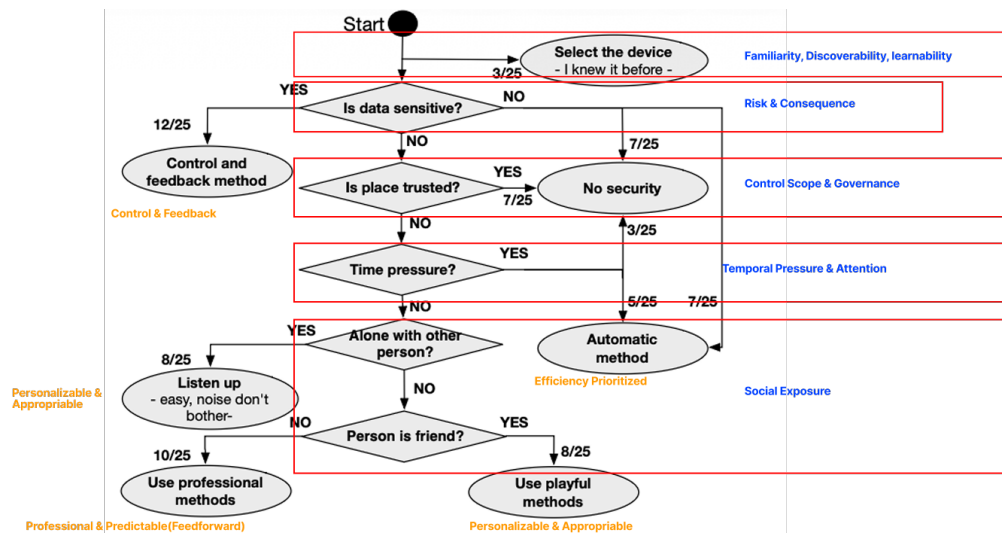


Figure 5.2: Adaptation of device pairing decision logic into social factor groups, adapted from Ion et al. (2010)

In order to provide more detail into how decision nodes and outcomes from the device pairing literature were adapted in this study, Table 5.4 demonstrates mapping these original elements to factors and outcomes relevant to the present research.

Table 5.4: Mapping from device pairing decision logic to social factor groups

Original decision element in pairing logic	Interpretation in the original context	Use in this framework	Reason for adaptation
Select the device / “I knew it before”	Familiarity with the target device and ability to recognize it before pairing.	Excluded from environmental social factors.	This depends strongly on a specific device, user history, discoverability, and learnability. It was therefore considered more suitable for product-specific evaluation than for general environmental analysis.
Is data sensitive?	Whether the data exchanged during pairing is perceived as sensitive or risky.	Mapped to <i>Risk factors</i> .	In an IoT control unit, the equivalent concern is not only data sensitivity, but also whether the action may create consequences for privacy, other users, or the controlled environment.
Is place trusted?	Whether the place is perceived as safe enough to reduce security-effort.	Mapped to <i>Hierarchy clarity factors</i> .	For indoor control, trust in place was reinterpreted as clarity about who is allowed to control the device, what rules apply, and whether the action is legitimate in that environment.

Original decision element in pairing logic	Interpretation in the original context	Use in this framework	Reason for adaptation
Time pressure?	Whether the user needs to complete the pairing process quickly.	Mapped to <i>Time factors</i> .	Time pressure was generalized as interaction urgency: how much delay, confirmation, exploration, or additional steps the situation can tolerate.
Alone with other person?	Whether the user is alone or accompanied during pairing.	Mapped to <i>Social exposure factors</i> .	The presence and proximity of other people may change how visible, socially exposed, or uncomfortable an interaction feels.
Person is friend?	Whether the surrounding person is familiar or socially close to the user.	Mapped to <i>Social exposure factors</i> .	The user's relationship to surrounding people affects whether informal, playful, or personal interaction feels acceptable, or whether the interaction should remain professional and predictable.
Control and feedback method	A pairing method that provides more user control and feedback.	Mapped to rich <i>Feedback</i> interaction method.	This was not treated as a contextual factor, but as a possible design direction when users need stronger control, confirmation, or feedback.

Original decision element in pairing logic	Interpretation in the original context	Use in this framework	Reason for adaptation
Automatic method	A low-effort method selected when security or control demand is lower.	Mapped to <i>Efficiency</i> prioritized interaction method.	This was adapted as a design tendency toward reducing interaction effort when the context supports efficient operation.
Listen up / playful methods	Informal or socially acceptable methods under certain social conditions.	Mapped to <i>Personalizable</i> interaction method.	These outcomes suggested that interaction style can depend on social appropriateness and the relationship between users.
Professional methods	More formal and predictable methods used when the situation is less socially relaxed.	Mapped to <i>Professional</i> with feedforward interaction method.	This was adapted as a design direction for contexts where users may prefer clear, formal, low-risk, and predictable interaction.

Due to the specific topic studied by Ion et al. (2010), not all aspects of device pairing interaction could be generalized to the broader context of using an indoor IoT control unit. For example, all kinds of familiarity factors were excluded from environmental social factors because of the strong dependence on the specific device, user experience, and learnability aspects. Such specific factors were more applicable in product-level evaluation rather than general environmental analysis. Thus, only those social factors that could be adopted to indoor control were selected.

The remaining social factors were specified further based on device pairing literature combined with various sources on context of use analysis, interaction involving multiple users, and intelligent systems. Four main factor groups were formed: *risk factors*, *hierarchy clarity factors*, *time factors*, and *social exposure factors*. Specific factors from each group were defined based on related literature in the area of context of use analysis, intelligent systems, environmental analysis, and interaction involving multiple users. Repeated factors and concepts related specifically to mobile phones or computers were eliminated. Moreover, specific terminology was modified in order to better fit the IoT control context.

Table 5.5 presents selected environmental social factors for the final framework.

Table 5.5: Environmental social factors for the framework

Factor group	Selected factor	Source concept	Adapted meaning
Risk factors	Task involvement	Task involvement in context modeling (Bauer & Dey, 2016)	How broadly the current interaction may affect the environment, other users, or the controlled system. In this research, a task with higher involvement means that the action may have consequences beyond the individual user.
Risk factors	Obtrusiveness	Obtrusiveness as a contextual attribute (Bauer & Dey, 2016)	The degree to which the interaction or its output may disturb, interrupt, or draw attention from surrounding people. This may include visible trial and error, sound, lighting changes, or other noticeable feedback.
Risk factors	Protecting privacy	Privacy protection as a social demand of the environment (Ronkainen et al., 2010)	Whether the interaction may reveal the user's intention, preference, identity, or control decision to other people nearby.
Hierarchy clarity factors	Hierarchy	Social hierarchy in interaction involving multiple users (Shavitt et al., 2021)	Whether there is a clear social or organizational hierarchy that defines who has a stronger right, responsibility, or authority to control the system.
Hierarchy clarity factors	Policy on device use	Policy on computer use in context of use analysis (Maguire, 2001)	Explicit or implicit rules that define what kind of device use is appropriate, allowed, or expected in a specific environment. The term was adapted from "computer use" to "device use" to fit the IoT control context.

Factor group	Selected factor	Source concept	Adapted meaning
Hierarchy clarity factors	Group dynamics	Group dynamics as part of social context (Bauer & Dey, 2016)	How multiple users coordinate, influence, conflict, or negotiate when using the same control unit or being affected by the same environmental change.
Time factors	Pace interaction urgency	/ Pacing in context of use analysis (Maguire, 2001); time constraints in interaction method choice (Ion et al., 2010)	How urgently the user needs to act and how much tolerance the situation allows for delay, exploration, confirmation, or additional interaction steps.
Social exposure factors	People present	People present in the environment (Ronkainen et al., 2010)	The number, proximity, and visibility of other people around the user during interaction. This affects whether the action feels observed or socially exposed.
Social exposure factors	User's relationship to people	User's relationship to people in the environment (Ronkainen et al., 2010)	The relationship between the user and surrounding people, such as strangers, colleagues, family members, guests, staff, or authority figures.
Social exposure factors	Psychological predispositions and phenomena	Psychological predispositions and phenomena in context modelling (Bauer & Dey, 2016)	Psychological or situational tendencies that may shape interaction, such as fear of making mistakes, conformity, social pressure, anxiety, or sensitivity to formal settings.

All these factors made up the social side of the environment component of the final framework. Based on selected social factors, it was possible to evaluate the extent to which the user may feel responsible, autonomous, or capable of managing the environment.

5.1.2.5 Decision-Making Impact

The next step was to translate environmental social factors into *decision-making impact*. This layer was introduced because social factors do not directly indicate interface solutions. Instead, they first influence how the user interprets the interaction situation. In a shared or semi-public environment, the user may need to judge whether the action is important, whether they are allowed to act, whether the system response will be socially visible, and whether they are capable of completing the action correctly. Therefore, the social factors were not connected directly to design guidelines, but were first interpreted through their effects on the user's decision-making process.

This part was mainly informed by the factors discussed by Shavitt et al. (2021) in relation to interaction involving multiple users. Their work identifies responsibility, autonomy, and self-efficacy as important dimensions in interaction with natural interfaces involving several users. These three concepts were adopted as the main decision-making impacts in the present framework because they describe how users may evaluate their own position in a social interaction situation. In the context of an indoor IoT control unit, they were interpreted as the user's sense of responsibility, the user's sense of autonomy, and the user's sense of self-efficacy.

User's sense of responsibility refers to the extent to which the user feels accountable for the consequences of interaction. This is affected mainly by risk factors and time factors. When the action may influence other users, disturb the environment, reveal private information, or produce visible consequences, the user may feel a stronger need to act carefully. At the same time, when the situation does not allow enough time for exploration or correction, responsibility may be experienced differently. Thus, responsibility was used to describe how much the interaction situation makes the user aware of consequence and accountability.

User's sense of autonomy refers to the extent to which the user feels allowed and socially permitted to act. This is affected mainly by hierarchy clarity factors and social exposure factors. If the hierarchy of control is clear, the policy of device use is understandable, and the user knows their relationship to other people in the space, the user may feel more autonomous. By contrast, unclear control rights, strong social exposure, or uncertainty about whether other people will judge the action may reduce the user's sense of autonomy. Autonomy therefore describes whether the user felt that they had the right, permission, and social space to interact with the control unit.

User's sense of self-efficacy refers to the extent to which the user feels capable of completing the interaction successfully. In this framework, self-efficacy was considered as a combined result of risk factors, time factors, hierarchy clarity factors, and social exposure factors. Even if the interface is physically usable, the user may still feel incapable if the consequence is high, time is limited, the control hierarchy is unclear, or other people are watching. Therefore, self-efficacy was used to describe whether the social situation supports the user's confidence in acting correctly and understanding the result of the action.

The mapping from environmental social factors to decision-making impacts is shown in Figure 5.3. Risk factors and time factors were mapped to the user's sense of

responsibility because they shape the perceived consequence and urgency of action. Hierarchy clarity factors and social exposure factors were mapped to the user's sense of autonomy because they affect the perceived permission and social freedom to act. All four factor groups were mapped to the user's sense of self-efficacy because confidence in interaction depends on both consequence-related and social permission-related conditions.

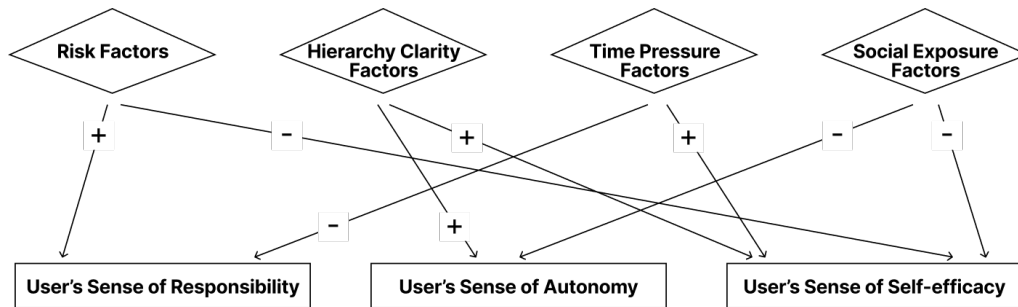


Figure 5.3: Mapping from environmental social factors to decision-making impacts

The three decision-making impacts are summarized in Table 5.6. These impacts were not used as psychological measurement scales. Instead, they were used as practical interpretation layers for translating social context into interaction implications.

Table 5.6: Decision-making impacts

Decision-making impact	Meaning
User's sense of responsibility	The extent to which the user feels accountable for the consequence of interaction, especially when the action may affect other users, shared resources, privacy, or the state of the controlled environment.
User's sense of autonomy	The extent to which the user feels allowed, socially permitted, and free to interact with the control unit in the current environment.
User's sense of self-efficacy	The extent to which the user feels capable of completing the interaction successfully and understanding the result of the action under the current social conditions.

In order to make these impacts usable in the framework, a simple qualitative scoring logic was introduced. Each factor group could be interpreted as supporting or not supporting a certain decision-making impact. The symbols “+” and “-” do not indicate whether a factor is good or bad in general. Instead, they indicate whether the factor state supports the specific decision-making impact being assessed. Non-applicable factors were excluded from the calculation.

For each decision-making impact, the final level was calculated based on the proportion of supporting factor states among the applicable factors. A supporting

state was scored as $1/n_{\text{applicable}}$, a non-supporting state was scored as 0, and non-applicable factors were excluded. If no factor was applicable, the decision-making impact was marked as not applicable. The interpretation of the score was qualitative: 0 was interpreted as low, $1/2$ as normal, and values above $1/2$ as high. This logic is summarized in Table 5.7.

Table 5.7: Scoring logic for social decision-making impacts

Decision-making impact	Supporting factor states	Score interpretation
User's sense of responsibility	Higher risk and lower time pressure support stronger responsibility.	0 = low; $1/2$ = normal; $> 1/2$ = high.
User's sense of autonomy	Clearer hierarchy and lower social exposure support stronger autonomy.	0 = low; $1/2$ = normal; $> 1/2$ = high.
User's sense of self-efficacy	Lower risk, lower time pressure, clearer hierarchy, and lower social exposure support stronger self-efficacy.	0 = low; $1/2$ = normal; $> 1/2$ = high.

These three impacts then became the basis for analyzing how social context may influence user interaction.

5.1.2.6 Effects on User Interaction

Based on the three decision-making impacts, the next step was to interpret how social context may affect user interaction. In this framework, the user's sense of responsibility, autonomy, and self-efficacy were used to indicate the interaction tendency that may be more suitable for a given context. This step was introduced because the three impacts still describe the user's position in the situation, rather than the interface direction itself.

The calculation logic is shown in Figure 5.4. The symbols “+” and “-” indicate whether a factor state supports the specific sense being assessed. They do not mean that a contextual factor is generally positive or negative. For example, a higher level of risk may support a stronger sense of responsibility, while a lower level of risk may support a stronger sense of self-efficacy. In the same way, lower time pressure may support responsibility and self-efficacy, while clearer hierarchy and lower social exposure may support autonomy and self-efficacy.

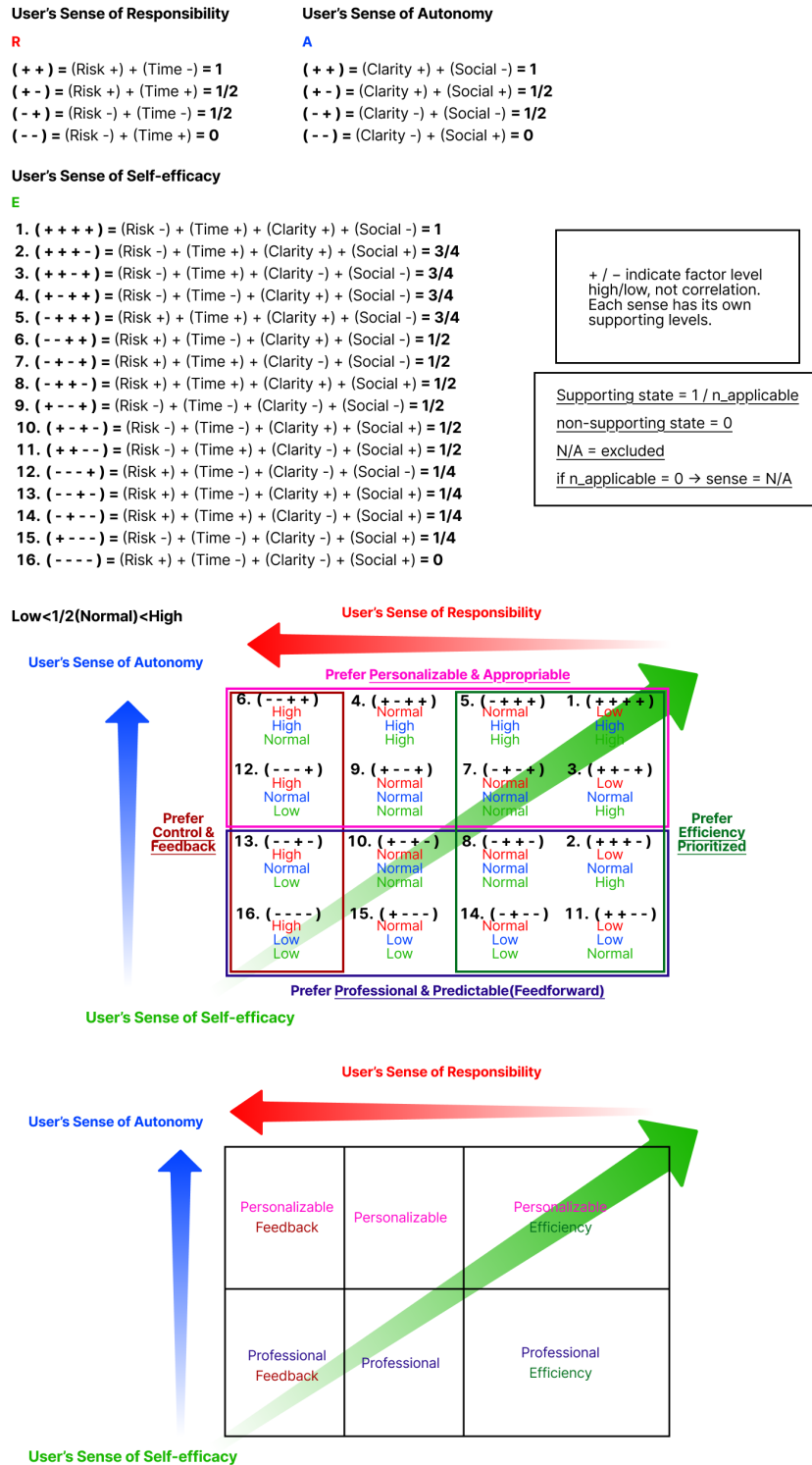


Figure 5.4: Calculation logic and interaction tendency matrix for social decision-making impacts

The user's sense of responsibility was used as one axis because it indicates how carefully the user may need to act. When responsibility is high, the interaction should give more control, confirmation, and feedback, since the user may feel accountable

for the consequences. When responsibility is lower, the interaction may allow more direct or efficient operation because the perceived consequence is lower.

The user's sense of autonomy was used to indicate whether the user feels socially allowed to act. When autonomy is high, the interaction can be more personalizable and appropriate to the user's own preference. When autonomy is low, the interaction should avoid making the user feel exposed or uncertain. In this case, a more professional, predictable, and clearly guided interaction may be more suitable.

The user's sense of self-efficacy was used to indicate how capable the user feels in completing the interaction. When self-efficacy is high, the interaction can prioritize efficiency, since the user is more likely to understand what to do and recover from small mistakes. When self-efficacy is low, the interaction should provide more guidance, feedforward, visible system state, and error prevention.

By combining the three impacts, four main interaction tendencies were formed: *control and feedback*, *efficiency-prioritized*, *professional and predictable*, and *personalizable and appropriate*. These tendencies were not used as strict categories. Instead, they were used to guide the designer toward the type of interaction that may better fit the social context.

Table 5.8: Interaction tendencies derived from social decision-making impacts

Interaction tendency	Typical condition	Design implication
Control and feedback	Higher responsibility, or contexts where the user needs to feel sure about the result.	Provide clearer feedback, confirmation, reversibility, and visible system state.
Efficiency-prioritized	Higher self-efficacy and lower perceived risk.	Reduce steps, support faster operation, and avoid unnecessary confirmation.
Professional and predictable	Lower autonomy or lower self-efficacy, especially in formal or socially visible settings.	Use clear feedforward, stable interaction logic, formal tone, and low-risk operation.
Personalizable and appropriate	Higher autonomy and enough self-efficacy, especially in personal or socially relaxed settings.	Allow preference adjustment, personalization, and interaction styles that fit the user's own situation.

This part of the framework translated social context into interaction tendency. For example, a hotel lobby situation may require a more professional and predictable interaction because the action is visible, related to roles, and may affect other people. A hotel room situation may allow more personalizable and efficient interaction because the user has more autonomy and the result is more private. In this way, the matrix helped connect social analysis to later design guidance without treating social context as a fixed label.

5.1.2.7 Design Suggestion: Environmental Social Factors

After the interaction tendencies were defined, the next step was to connect them with possible design suggestion areas. Similar to the physical side, this part of the framework did not aim to generate fixed interface solutions. Instead, it provided a reference layer that helps designers know which design principles should be considered when a certain social interaction tendency appears in a scenario.

The main reference sources for this part were ISO 9241-110 and ISO 9241-112. ISO 9241-110 was useful because it provides interaction principles related to task suitability, self-descriptiveness, conformity with user expectations, controllability, use error robustness, learnability, and user engagement (International Organization for Standardization, 2020). ISO 9241-112 was useful because it provides presentation principles related to detectability, discriminability, unambiguous interpretability, conciseness, and consistency (International Organization for Standardization, 2017).

For example, when the social context suggests a need for *control and feedback*, the designer should pay more attention to controllability, feedback, confirmation, reversibility, and use error robustness. When the context suggests *efficiency-prioritized* interaction, the designer should examine suitability for the user's tasks, conciseness, and reduced unnecessary steps. When the context suggests a *professional and predictable* interaction, the designer should consider self-descriptiveness, conformity with user expectations, consistency, and clear feedforward. When the context suggests *personalizable and appropriate* interaction, the designer should consider controllability, user engagement, learnability, and whether the interaction can be adapted without creating confusion or risk.

The mapping between interaction tendencies and design suggestion areas is summarized in Table 5.9. This table should be understood as a guide for selecting relevant design principles, not as a fixed checklist. In actual design work, the final decision still depends on the specific scenario, user role, task goal, and product constraints.

Table 5.9: Design suggestion sources for environmental social factors

Interaction tendency	Design suggestion areas	Main reference source
Control and feedback	Feedback; confirmation; visible system state; reversibility; controllability; use error robustness.	ISO 9241-110: Controllability and use error robustness; ISO 9241-112: detectability and unambiguous interpretability.
Efficiency-prioritized	Fewer interaction steps; direct access to frequent actions; concise presentation; reduced unnecessary confirmation; task-focused operation.	ISO 9241-110: Suitability for the user's tasks; ISO 9241-112: conciseness and consistency.

Interaction tendency		Design suggestion areas	Main reference source
Professional and predictable		Clear feedforward; stable interaction logic; formal and neutral tone; clear labels; predictable system response; low-risk exploration.	ISO 9241-110: self-descriptiveness and conformity with user expectations; ISO 9241-112: consistency and unambiguous interpretability.
Personalizable and appropriate		Adjustable preferences; suitable level of control; adaptable feedback; user engagement; support for repeated use and learning.	ISO 9241-110: Controllability, user engagement, and learnability; ISO 9241-112: consistency and discriminability.

Through this step, the social side of the framework became connected to design guidance. The framework first identifies the relevant social factors, then translates them into the user's sense of responsibility, autonomy, and self-efficacy, then interprets the suitable interaction tendency, and finally points the designer toward relevant design principles. This helped avoid making a direct and unsupported jump from social context to interface features.

5.1.2.8 User Role and Task Hierarchy

The third part of the framework focused on user role and task hierarchy. This part continued from the initial framework, where user groups, frequency of use, and experience level were already considered important. However, the final framework did not use fixed user role categories such as device manager, general user, and restricted user as the main matching method. These categories were useful for understanding different levels of control responsibility, but they were less flexible when the framework was applied to different contexts.

Instead, the final framework uses user groups in a scenario and matches them according to their expected frequency of use and relevance to the control unit. In this way, the user role is not decided by a fixed identity, but by how often and how directly a group needs to interact with the system in a specific context. For example, in a hotel room, the guest may be the primary user for comfort-related controls, while cleaning staff may be a secondary user for reset and maintenance-related tasks. In a hotel lobby, the front desk staff or cleaning staff may become the primary user depending on the task, while guests may be only affected users.

This approach made the user role part more adaptable. The same person type may have a different role in another context, and the same control unit may need to support different primary or secondary users in different scenarios. Therefore, the framework requires designers to first list the user groups involved in the scenario, and then decide which group should be considered primary, secondary, or occasional based on expected use frequency, control responsibility, and task relevance.

Table 5.10: User group matching logic in the framework

User group level	Meaning	Design implication
Primary user group	The user group that interacts with the control unit most frequently or has the most direct task need in the scenario.	The main interaction layer should support this group first. Frequently used functions should be clear, fast, and easy to reach.
Secondary user group	The user group that uses the control unit less frequently, or only for specific tasks.	The interface should still support this group, but not at the cost of making the main interaction too complex.
Occasional user group	The user group that uses the control unit rarely, temporarily, or only under specific conditions.	The interaction should be safe, understandable, and limited to necessary functions. Guidance and clear feedback become more important.

After the user groups were matched, task hierarchy was used to decide which functions should be placed in the main interface and which should be placed deeper. This hierarchy was based on two main considerations. The first was the expected frequency and complexity of different indoor IoT control functions. The second came from the user study, especially the parts where participants discussed which functions should be available to guests, temporary users, or people with lower responsibility.

The user study showed that participants generally accepted guests or temporary users using simple and low-consequence functions, such as turning lights on or off, adjusting brightness, changing temperature within a reasonable range, or using music and basic scene controls. However, participants were more cautious about functions that make lasting changes, affect automation, change routines, manage access, or influence system configuration. These functions were usually seen as belonging to the owner, host, staff member, or another responsible user. This became an important basis for the task hierarchy.

Therefore, the task hierarchy separates basic operation from deeper configuration. Level 1 and Level 2 functions are treated as common control tasks. They should usually be visible and easy to access, because they are closely related to frequent use and immediate environmental adjustment. Level 3 and Level 4 functions involve more persistent changes, wider control scope, or system management. These should usually be placed deeper, require clearer confirmation, or be limited to user groups with higher responsibility.

Table 5.11: Task hierarchy for indoor IoT control units

Task level	Task type	Meaning and design implication
Level 1.1	On and off	The most basic control task. It should usually be accessible to the main user group and often also to temporary users, depending on the context.
Level 1.2	Predefined values	Simple selection of existing settings, such as scenes or preset comfort levels. These functions can support fast use and reduce the need for detailed adjustment.
Level 2.1	Specific value adjustment for one device	Adjustment of a specific value, such as brightness, temperature, blind position, or another device index. These functions should be ordered according to use frequency in the specific context.
Level 2.2	Temporary scene adjustment	Temporary changes to an existing scene or environmental setting. This gives more control than preset selection, but should still be recoverable and easy to reset.
Level 3.1	Changing scene presets and checking status	Editing existing presets or checking system state. This level requires more understanding of the system and should not be exposed too strongly to occasional users.
Level 3.2	Adding or removing scenes	Creating or deleting scene settings. These changes are more persistent and should usually be limited to responsible users.
Level 4.1	Controlling spatial boundaries	Changing which area, room, or device group is affected by an action. This level has higher consequence because it changes the control scope.
Level 4.2	Controlling device hierarchy and maintenance	Managing relations between devices, permissions, automation, or system maintenance. This level should normally be protected or placed in a deeper layer.

The task hierarchy also helped define the functional depth of the control unit. It was not only used to organize existing functions into different interface layers, but also to decide which task levels should be included in the device according to the selected user groups. If the main user group only needs frequent and basic control, the control unit may only need to support Level 1 and Level 2 tasks. If the main user

group has higher responsibility, such as staff, facility workers, or device managers, the device may need to include Level 3 or Level 4 tasks as well.

This was important because an indoor IoT control unit does not always need to provide the full range of possible functions. A control unit designed for guests or occasional users may become confusing if it includes advanced configuration tasks. On the other hand, a control unit designed for responsible staff may be insufficient if it only provides simple scene selection.

In this way, the user role and task hierarchy side translated user context into function priority and functional depth. It helped decide which functions should be included in the control unit, which should be visible, and which should be simplified, protected, or placed in deeper layers. Together with the physical and social branches, it completed the framework by connecting environmental conditions, social decision-making, and user task needs to design guidance.

5.2 Framework Implementation in Design Projects

The framework was developed as a design support tool. Its purpose is to help designers move from a description of context toward interaction requirements. It helps identify what the control unit needs to support in a specific use situation, such as suitable interaction modality, feedback, feedforward, control scope, function priority, and local function depth.

The framework can therefore be implemented through three main steps.

1. Identify typical scenarios

The first step is to define the scenario input for the framework. If the project focuses on one specific situation, the designer can directly describe that situation. If the project focuses on a broader target category, the designer should identify several typical scenarios within that category. A typical scenario should be selected based on typical users, typical tasks, and typical use situations. The selected scenarios should also cover different conditions within the broader category as much as possible. For example, commercial places may include hotel rooms, hotel lobbies, office lobbies, personal offices, and restaurants. These scenarios are all commercial contexts, but they differ in privacy level, social exposure, user responsibility, and task complexity.

2. Analyze each specific scenario separately

Each selected scenario should then be analyzed as a separate case. The framework should not merge all scenarios too early, because important contextual differences may disappear. For each scenario, the analysis should cover the following parts:

- **Physical factor analysis**

Identify environmental conditions that may affect visual output, tactile output, audio input and output, or manual input.

- **Social factor analysis**

Identify social conditions related to risk, hierarchy clarity, time pressure, and social exposure. These factors are translated into the user's possible sense of responsibility, autonomy, and self-efficacy.

- **User group and task hierarchy analysis**

Identify which user groups should be prioritized in the scenario and which task levels should be supported locally.

- **Design suggestion matching**

Match the analysis results with relevant design suggestions. The physical analysis points toward modality and accessibility guidance. The social analysis points toward interaction tendency and feedback needs. The user and task analysis points toward function priority, task access, and local control depth.

3. Synthesize across scenarios

After the individual scenarios have been analyzed, the designer compares the results across all selected scenarios. The aim is to identify common requirements and important differences. Common requirements can be used to form the main design direction for the broader target category. For example, if several commercial scenarios require clear control scope, fast access to frequent actions, feedback, and limited local function depth, these can be treated as typical design requirements for the target commercial control unit.

At the same time, differences between scenarios should not be ignored. They may indicate where the product needs configuration options, different layout variants, or context-specific installation decisions.

Through this process, the framework supports design reasoning at two levels. At the scenario level, it helps to translate a concrete context into interaction requirements. At the cross-context level, it helps compare multiple scenario analyses and extract more stable design implications for a broader design target.

5.3 Commercial Project Design Study

After the framework was developed, it was applied in a commercial project design study. This part of the project was carried out together with the partner company and focused on how the framework could support the design of an indoor IoT control unit in a more realistic product context. The initial target was discussed with the partner company, and the project direction was narrowed toward commercial environments.

5.3.1 Scenarios

Commercial environments were selected because they include more variation in users, tasks, social conditions, and levels of control responsibility. A control unit in a commercial place may be used by staff, visitors, guests, cleaners, customers, or temporary users. The same product may also need to support different levels of

interaction, from simple comfort adjustment to more operational or maintenance-related control. This made commercial environments suitable for testing whether the framework could help structure design decisions across different contexts.

Since commercial environments still cover a wide range of possible places, five scenarios were selected as starting points for design exploration. The aim was not to cover all possible commercial contexts, but to select scenarios that were different enough from each other to expose different interaction requirements. The selected scenarios were hotel room, hotel lobby, office lobby, personal office, and restaurant. These scenarios differed in privacy level, user role, control responsibility, task complexity, and social exposure.

Table 5.12: Selected commercial scenarios for framework analysis

Scenario	Main user groups	Reason for selection
Hotel room	Guest, cleaning staff, maintenance team	A more private commercial context with first-time users, comfort control, and temporary access.
Hotel lobby	Front desk staff, cleaning staff, guests	A shared and visible context with stronger role expectations, operational tasks, and social exposure.
Office lobby	Staff, visitors, facility workers	A semi-public workplace context where users may be affected by the environment but may not always feel allowed to control it.
Personal office	Office worker, visitor, facility staff	A more personal work context with stronger ownership feeling and more stable daily use.
Restaurant	Staff, customers, manager	A service context where lighting, scenes, and atmosphere may affect both business operation and customer experience.

5.3.2 Framework Analysis in Commercial Scenarios

Then each scenario was analyzed through the framework. The analysis considered physical factors, social factors, user groups, and task hierarchy. The physical side was used to identify possible modality and accessibility issues. The social side was used to understand whether the interaction should lean toward feedback, efficiency, professional predictability, or personalization. The user and task side was used to decide which user groups should be prioritized and how deep the control functions should go in each scenario. The detailed analysis tables for the five scenarios are included in Appendix D.

The social scenario matrix also helped clarify the main interaction direction, as shown in Figure 5.5. The five scenarios did not distribute evenly across all possible

interaction tendencies. Only one scenario was positioned strongly toward personalizable efficiency. In comparison, most scenarios were closer to professional, feedback, or professional feedback-related areas. Therefore, the design direction did not focus primarily on personalization as the main interaction quality.

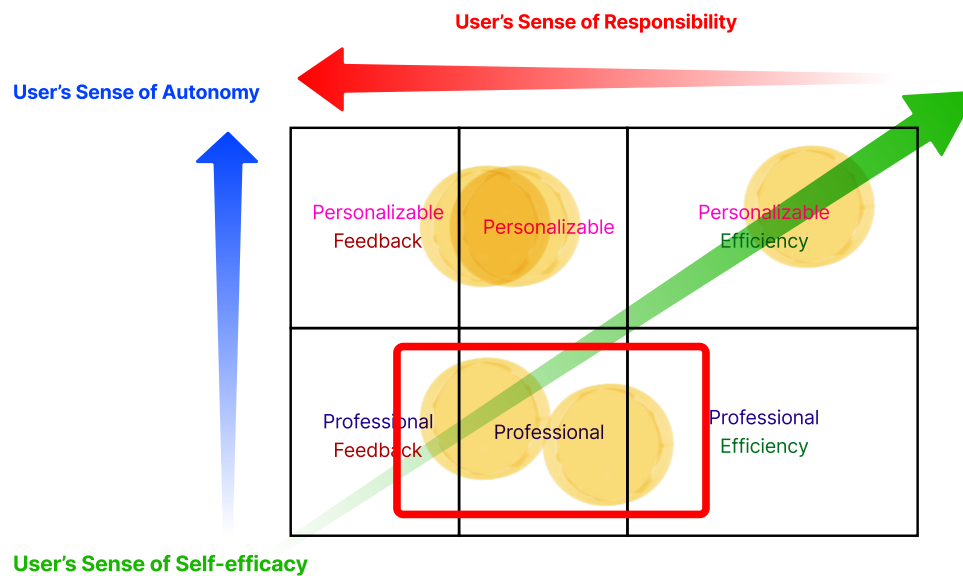


Figure 5.5: Scenario matrix and selected focus direction for commercial control interaction

It suggested that personalization should not become the leading design principle for this control unit. A professional and feedback-oriented interaction can still be usable in more personal contexts, because it provides clarity, predictability, and confidence. However, an interaction designed mainly around personalization may not fit professional or shared commercial contexts, where users need to act clearly, quickly, and with lower social risk. For this reason, feedback, feedforward, and professional predictability became a stronger focus in the following design work.

Across the five scenarios, several common design requirements were identified.

- **1.** The control unit needed to make the control scope clear. Users should understand what area, device, or scene will be affected before they act. This was important especially in shared commercial places, where one action may influence other people.
- **2.** The system needed to support fast access to frequent actions. Basic tasks such as turning lights on or off, selecting a scene, adjusting brightness, or changing a comfort setting should not require deep navigation. These functions are likely to be used by primary or frequent users and should be placed close to the first interaction layer.
- **3.** The control unit needed to support both quick scene control and a certain level of fine control. The scenario analysis showed that target user groups did not only need to trigger predefined scenes. In several contexts, users also needed to adjust a specific area such as changing the ceiling lamp area,

adjusting brightness in one part of a room, or making a temporary correction during cleaning or service work. Therefore, the device should not be limited to one button scene selection only. It should also support Level 2 tasks, where users can make specific value or area-based adjustments when the scenario requires it. At the same time, the task hierarchy suggested that the functional depth of the device should mainly cover Level 1 and Level 2 tasks. Level 1 tasks include basic on and off control and predefined values or presets. Level 2 tasks include more specific adjustment of a device, room, or area. More advanced tasks, such as scene preset configuration, adding or removing scenes, routine setting, device hierarchy, and maintenance, can be handled through the app or other parts of the existing system ecosystem. In this way, the control unit can become a clear and useful local control point while still fitting into a larger smart environment system.

- **4.** The control unit needed to separate simple operation from deeper configuration. Temporary users, guests, or customers may need basic control, but they should not be exposed to advanced settings that change scenes, device groups, automation, or system logic. More persistent or higher consequence functions should be placed deeper or limited to users with higher responsibility.
- **5.** Feedback and feedforward were needed to support trust and reduce mistakes. In commercial environments, users may hesitate when they are unsure what will happen or whether the command has worked. The scenario matrix further supported this direction, since most scenarios required professional, predictable, or feedback-oriented interaction rather than highly personalized interaction. Therefore, the control unit should show current state, expected effect, and result of action clearly.
- **6.** The analysis suggested that the control unit should avoid relying on one single modality. In some commercial scenarios, voice or audio feedback may be inappropriate because of social exposure or background noise. In other scenarios, visual output may be limited by distance, lighting conditions, or viewing angle. Therefore, the design needed to combine different forms of interaction and feedback rather than depend on only one channel.

Based on this, the design direction moved away from a pure touch display interface. A touch display may provide flexibility, but it can also make the interaction depend too strongly on visual attention and screen interpretation. It may also create uncertainty about whether the display is meant to be touched, read, or both. Therefore, the concept direction moved toward physical buttons with tactile feedback, combined with visual feedback. Physical buttons could provide clearer affordance and tactile confirmation, while the display could be used mainly for labels, system state, feedforward, and feedback.

5.3.3 Broad Ideation

Based on the user study insights and the scenario analysis through the framework, the project moved into a broad ideation phase. The aim was to explore possible directions for function, modality, and interaction. The ideas were still fragmented, but they helped turn the framework output into more concrete design elements.

The ideation focused on three main areas. The first was input modality, including physical buttons, knobs, and sliders. Since the scenario analysis suggested avoiding reliance on a single modality or a pure touch display interface, physical interaction became an important direction. Different physical input types were considered in terms of click, press, rotation, movement, tactility, and possible feedback.

The second area was function. The control unit needed to help users understand the device, understand the control scope, receive feedback about the current state, and complete different control tasks. This included ideas such as connection indicators, target and area indicators, scene status, selection feedback, action result feedback, and task progress feedback.

The third area was visual output. Several display and feedback options were considered, including TFT LCD, reflective LCD, segmented LCD, OLED, e-paper display, dot matrix display, backlight with custom front plate, printed or manufactured labels, no display, and LED lights. These options were considered as possible ways to support labels, system state, feedforward, and feedback without turning the whole interface into a touch screen.

The broad ideation was then summarized into a table of possible design directions. This table helped compare which ideas were related to functions, which were related to input modality, and which were related to visual output.

Table 5.13: Summary of broad ideation directions

Area	Ideation content	Design meaning
Input modality	Physical buttons, including momentary switch, locking switch, and Hall effect switch.	Buttons were considered because they can provide clear affordance, direct operation, and tactile feedback.
Input modality	Button interaction variations, including single click, multiple click, long press, double press and hold, press hardness, press depth, and press speed.	These variations showed possible ways to increase interaction richness without relying only on a touch screen.
Input modality	Physical knobs, including Z axis input, X and Y axis input, watch dial, press and turn, and different rotation types.	Knobs were considered for fine control, especially when the user needs to adjust brightness, temperature, blind position, or another continuous value.

Area	Ideation content	Design meaning
Input modality	Slider interaction, including regular slider, momentary slider, locking slider, endpoint tactile events, and one axis dragging.	Sliders were considered for direct value adjustment, but were less flexible when the device needed to support many different control targets.
Function	Connection status, connection problem indicator, and fine connection indicator.	The device should show whether it is connected and whether the system can respond to the user's action.
Function	Control scope, including space hierarchy, matched channels and targets, target response, and interface indication.	Users should understand what area, device, or function will be affected before they act.
Function	Corresponding target status, including scene status, selection feedback, and guidance for observing real-world results.	The interface should help users understand the current state of the selected target or scene.
Function	Action completeness, including done, error, in progress, and progress indication for longer tasks.	The device should show whether an action has been completed, failed, or is still being processed.
Function	Task options, including scenes and fine control at scene level.	The device should support both quick scene activation and more specific adjustment when needed.
Function	Adaptation to different user types, including different interactions and setting lock.	The device should allow different depth of control for different user groups and levels of responsibility.
Visual output	Display options, including TFT LCD, reflective LCD, segmented LCD, OLED, e-paper display, segmented e-paper display, and dot matrix display.	These options were considered for showing labels, status, control scope, and feedback.
Visual output	Low information output, including backlight with custom front plate, printed or manufactured labels, no display, and LED lights.	These options were considered when the product needs simpler feedback, lower cost, or lower visual complexity.

This broad ideation helped define the next step of concept development. The design direction should combine physical input with visual feedback, support both scenes and fine control, show clear control scope and system state, and avoid exposing advanced settings directly on the local control unit.

5.3.4 Commercial Aspect and Marketing Intervention

After the broad ideation phase, the project moved from open design exploration toward a more commercially grounded direction. Since this was a design study conducted with a partner company, the concept could not be developed only from the framework and user study insights. It also needed to respond to product strategy, market expectations, competitor products, technical feasibility, cost, size, and how the device could fit into an existing smart environment ecosystem.

This step can be understood as a commercial intervention in the design process. The framework analysis had already suggested what the control unit should support from a use context perspective, such as clear control scope, physical buttons, visual feedback, quick access to frequent actions, and support for both scene control and fine control. However, the partner company and market situation introduced another layer of questions. The design also needed to consider what kind of product would be realistic, understandable, manufacturable, and competitive.

Therefore, two aspects were considered before the concepts were further developed. The first was the partner company's commercial and product-related requirements. The second was competitor analysis, which helped position the project in relation to existing smart control products and identify what kind of design direction may be more feasible in the market.

5.3.4.1 Partner Requirements

The first commercial input came from the initial scope discussion with the partner company. The original scope included several broad directions, such as mechanical design, electronics, interaction design, usability, technical feasibility, production aspects, cost, installation, and integration with the existing product ecosystem. However, these requirements did not have the same priority within the time frame of this thesis. Since the main research focus was how context factors can be translated into interaction design guidance, the concept development focused more on the requirements that were most closely connected to understandability, control clarity, user interaction, and use across different contexts.

The most important requirement was understandability. In the scope discussion, the main goal was expressed as making the current type of control situation easier to understand. This matched closely with the framework direction, since a large part of the framework also focused on control scope, feedback, feedforward, user roles, and task hierarchy. In other words, the partner requirement did not conflict with the research direction. Instead, it strengthened the idea that the control unit should help users understand what each button does, what area or function it controls, and what result can be expected after interaction.

This requirement was especially important in shared and commercial environments. The partner company mentioned that the product may be used in hotels, offices, homes, entrances, classrooms, and other spaces where users may not always be familiar with the device or people around. This supported the decision to use a display mainly for labels, system state, feedforward, and feedback.

Another important requirement was the problem of unused or unclear buttons. In a physical button product, the number of buttons is usually fixed, while the number of active scenes, channels, or functions may vary between contexts. This can create dead buttons or buttons whose purpose is unclear. From the user side, this creates confusion because the user may not know whether a button is inactive, unassigned, or simply controlling something they cannot see. From the commercial side, it also creates a product challenge because one hardware layout needs to fit different contexts.

A further requirement was that the product should remain realistic as a commercial product. The partner company emphasized that cost, installation, and value in the product chain needed to be considered. This meant that the design could not only aim for maximum interaction richness. It also needed to consider whether the end user, installer, and other actors in the value chain would understand the benefit of the product. As a result, the design direction had to balance clear interaction, physical feasibility, cost awareness, and compatibility with the existing ecosystem.

Overall, the partner requirements helped narrow the broad ideation into a more focused direction. The control unit needed to be understandable, physically clear, suitable for different shared environments, and able to handle variation in button functions without creating dead or confusing controls. These requirements became an important commercial layer on top of the framework-based design direction.

5.3.4.2 Competitor Analysis

In addition to the partner requirements, a competitor analysis was carried out to understand how existing products approach similar control problems. The analysis focused on selected products that were relevant to the project scope, especially products that combine physical input, visual feedback, scene control, fine control, or local smart environment control.



Figure 5.6: Selected competitor products used in the design study

The analyzed products included Sonoff NSPanel, Aqara Touchscreen Dial V1, Philips Hue Tap Dial Switch, IKEA BILRESA remote control, and Logitech MX Creative Console. Some supporting products, such as hubs and light bulbs, were ordered as part of the setup. The selected competitor products are shown in Figure 5.6.

The analysis showed that physical controls alone are not enough. In many physical control products, the button itself is clear as an input object, but its meaning is not always visible. Users may need to remember what the button controls or check the setup in an app. This was directly connected to the partner requirement of making the product understandable. Therefore, one important design direction was to combine physical buttons with readable and changeable visual information.

Another implication concerned fine control. Products with dials or scroll wheels showed that physical rotation can be useful for adjustment tasks such as brightness, temperature, blind position, or other continuous values. This supported the earlier framework implication that the local control unit should not only trigger predefined scenes, but also support Level 2 adjustment when users need more specific area or value control.

The analysis also reinforced the dead button problem. Fixed button products may work well when every button has a clear function, but the number of scenes, channels, or targets can vary between contexts. Two possible directions were therefore identified. One was to keep the button layout fixed but use dynamic or changeable labels to make each button readable. The other was to question whether the number of visible buttons should be physically fixed at all.

Overall, the competitor analysis worked as a commercial filter for the framework-based design direction. It helped refine how the physical button direction should be developed: the product should use physical input, readable labels, visual feedback, support both scene control and fine control, keep the local function depth limited, and consider possible ways to handle the dead button issue.

5.3.5 Design Solution

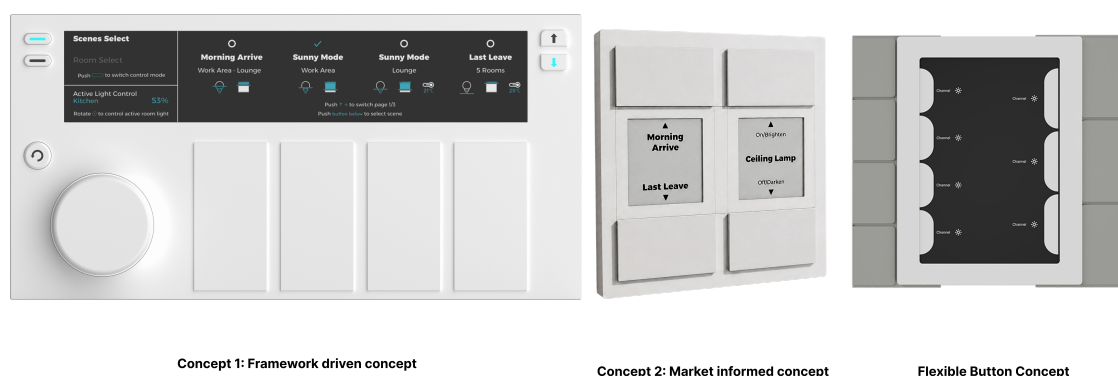


Figure 5.7: Overview of the three design outputs from the commercial project design study

Based on the framework analysis, broad ideation, partner requirements, and competitor analysis, the design work was developed into three design outputs, as shown in Figure 5.7. Two of them were main interface concepts and were later used in the concept evaluation. The third one was a separate physical product idea that responded to the dead button problem from a hardware perspective.

The purpose of developing more than one concept was not only to compare visual alternatives. The concepts represented different design logics. Concept 1 stayed closer to the framework direction and explored how one control unit could support a broader range of contexts, user roles, and task levels. Concept 2 responded more strongly to commercial concerns, especially compactness, lower manufacturing complexity, and easier market fit. The flexible button concept was developed separately as another possible response to the problem of unused or unclear buttons.

5.3.5.1 Concept 1

Concept 1 was developed mainly from the framework direction. It aimed to support a broader range of commercial scenarios, user roles, and task levels. The concept therefore kept a relatively rich control structure and provided both scene control and channel control. Instead of treating scene selection as the only local task, Concept 1 also allowed more detailed control of channels and areas when the scenario required it.

The main idea of Concept 1 was to make the relationship between scenes, channels, and controlled areas more explicit. This responded to the framework requirement of clear control scope. Users should be able to understand what they are controlling, what area is affected, and what system state is currently active. For this reason, Concept 1 contained more visual information and more structural separation between different control types.

Concept 1 also responded to the dead button problem through page switching. Instead of requiring every physical button to always represent one fixed function, the device could change the displayed page and update the button labels accordingly. In this way, the same physical buttons could represent different scenes, channels, or control targets depending on the active page. This allowed the concept to support more functions without adding more physical buttons to the hardware.

This direction made Concept 1 more flexible, but also more complex. The user needed to understand not only the button labels, but also which page was active and how the page related to the current control scope. Therefore, Concept 1 was closer to a complete local control interface. It was useful for exploring the framework direction, but it also carried a higher learning burden.

In terms of interaction, Concept 1 followed the direction of physical buttons combined with visual feedback. The display was not treated as the main input surface. Instead, it was used to support labels, system state, feedback, and feedforward. This was intended to reduce the ambiguity of physical buttons while avoiding a pure touch display interface.

5.3.5.2 Concept 2

Concept 2 was developed with stronger influence from the commercial and market-related analysis. It kept the same basic direction of physical input and visual feedback, but reduced the visible complexity compared with Concept 1. The aim was to create a more compact and approachable local control unit.

The main design intention of Concept 2 was first-use clarity and commercial feasibility. Instead of trying to cover a large number of functions in one unit, Concept 2 worked more like a simple local control unit with a limited number of clearly readable controls. This helped reduce interface complexity and also made the product direction more compatible with lower manufacturing cost.

Concept 2 addressed changing control needs in a different way from Concept 1. Rather than using page switching to fit more functions into one device, it accepted a more limited local function scope. If a space required more control points or more functions, multiple units could be installed. In this way, the product could remain simple and compact, while larger or more complex spaces could still be supported through several units.

This direction also reduced the risk of turning the device into a small control center. It kept the focus on local control, readable labels, and fast operation. The tradeoff was that Concept 2 depended more on correct placement, naming, and system setup. It was less flexible than Concept 1 as a single device, but it was easier to understand and more realistic as a standardized commercial product.

5.3.5.3 Flexible Button Concept

The flexible button concept was developed separately from the two main interface concepts. It was not used as a main evaluation concept, because it was less directly connected to the framework comparison. Instead, it responded to a more specific physical product issue that became important through the partner requirements and commercial analysis: the dead button problem.

The dead button problem occurs when the number of physical buttons does not match the number of active scenes, channels, or functions in a specific installation. If a product has a fixed number of buttons, some buttons may become inactive or unclear in certain contexts. From the user side, this can create confusion. From the product side, it makes one hardware layout harder to adapt across different installations.

Concept 1 responded to this problem through page switching, while Concept 2 responded by limiting the function scope of each unit and allowing multiple units when more control is needed. The flexible button concept explored a third direction. Instead of solving the problem through software pages or multiple devices, it questioned whether the number of visible buttons could be changed physically.

By using a reversible or physically reconfigurable button surface, the same product could support different button counts in different contexts. This would allow the product to adapt to different numbers of scenes or control targets without presenting inactive buttons to users.

This concept was treated as an additional design outcome rather than a main interface concept. It showed that the commercial project did not only raise interface structure questions, but also physical product questions. While Concept 1 and Concept 2 focused on different ways of combining physical buttons with visual feedback, the flexible button concept explored another way of handling variation in button functions at the hardware level.

5.3.5.4 Concept Operation Details

Before summarizing the design solutions, this section explains how the three design outputs are intended to be used. The aim here is not to repeat the design reasoning, but to clarify the basic interaction logic of each concept.

5.3.5.4.1 Concept 1 operation logic. Concept 1 is based on a larger control unit with physical buttons, a display area, page switching buttons, two control mode buttons, and a rotary control area. Its operation is shown in Figure 5.8. The interface is divided into several functional areas: control mode, scene or area selection, page change, action feedback, and channel control.

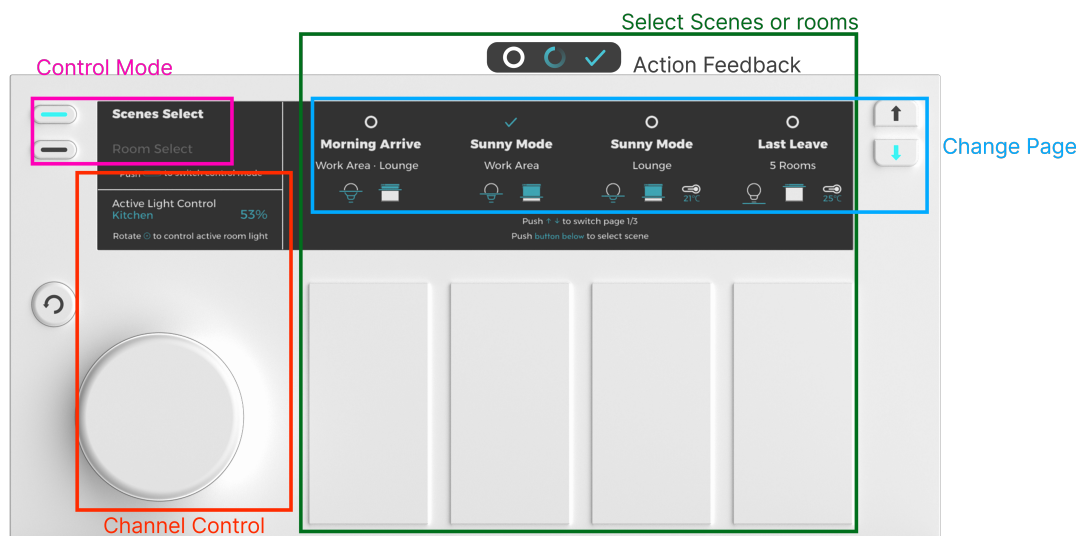


Figure 5.8: Operation logic of Concept 1

Concept 1 has two main control modes: *Scenes Select* and *Areas Select*. The user switches between these two modes using the two physical control mode buttons on the left side of the device. The lighting on these buttons indicates which control mode is currently active. When a control mode is active, the corresponding button light is on. When it is inactive, the light is off. This gives the user a physical indication of the current mode before they act.

In *Scenes Select* mode, the main physical buttons are used to select or activate scenes, as shown in Figure 5.9. Each scene shown on the display corresponds to one physical

button below it. The display shows the scene name, the area or rooms affected, and the device types included in the scene. This helps the user understand the control scope before pressing the button.

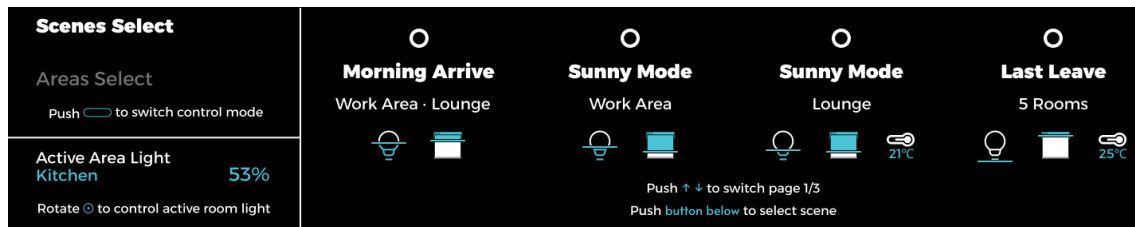


Figure 5.9: Scenes Select page in Concept 1

In *Areas Select* mode, the same physical button area is used to select a room or area as the active control target, as shown in Figure 5.10. Once an area is selected, it becomes the active area for the channel control. The active area is shown in the left control panel together with the current light value. This allows the user to understand which area will be affected by the rotary control.

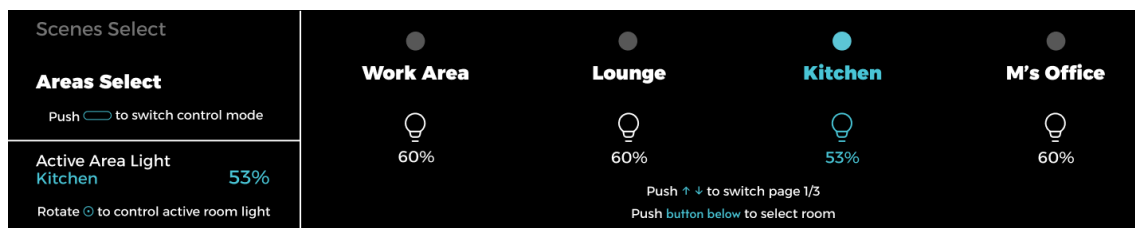


Figure 5.10: Areas Select page in Concept 1

The page change buttons on the right side are used when there are more available scenes or areas than can be displayed on one page. The button light indicates whether a page change is available. When another page can be reached, the corresponding page button lights up. When no further page is available in that direction, the light is off. This avoids making the user press a button that has no available action.

The top part of the display provides action feedback. It shows whether the selected item is inactive, being processed, or successfully activated. This helps the user understand whether the system has received the action and whether the result has been completed.

The rotary control area supports fine control of the active area. After the user selects an area in *Areas Select* mode, the large dial can be used to adjust the active area light level. Importantly, the dial can still control the selected active area even when the interface is later switched back to *Scenes Select* mode. This means that the user can keep a frequently used area as the active area and quickly adjust it without leaving the scene selection page. For example, a staff member could keep the kitchen or work area as the active area and still browse or trigger scenes while retaining fast access to light adjustment.

In this concept, the display mainly explains what the physical controls currently mean. The user does not need to touch the display. Instead, the display provides labels, page information, system state, feedforward, and feedback, while the physical buttons and dial provide the main input.

5.3.5.4.2 Concept 2 operation logic. Concept 2 uses a simpler and more compact operation logic than Concept 1. It is based on a standard four-button layout, where each button is paired with a visible label area. The device does not use page switching. Instead, the function of each button is shown directly through the label area in the center of the unit.

There are two main use configurations for Concept 2. The first configuration is used when the unit only controls scenes, as shown in Figure 5.11. In this case, the four physical buttons correspond to four scene actions. The user reads the scene names on the label areas and presses the corresponding physical button to activate the desired scene. This makes the interaction close to a traditional scene switch, but with clearer and changeable labels.

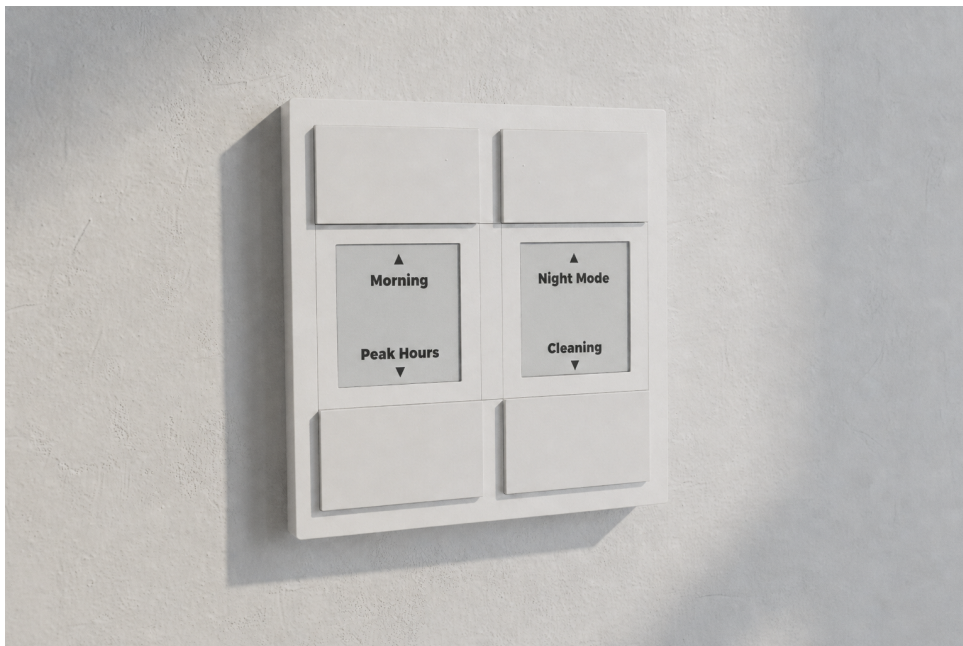


Figure 5.11: Concept 2 configuration with four scene control buttons

The second configuration combines scene control with channel control, as shown in Figure 5.12. In this configuration, one pair of buttons can be used as a channel control. The upper and lower buttons correspond to opposite actions for the same channel. For example, the upper button can be used for on or brighten, while the lower button can be used for off or darken. A short press can turn the channel on or off, while a long press can adjust the value, such as dimming or brightening a ceiling lamp.



Figure 5.12: Concept 2 configuration with scene control and one channel control

This means that Concept 2 does not try to include many control targets in one unit. Instead, each unit provides a limited number of clearly readable functions. If more scenes, areas, or channels need to be controlled, more units can be installed in relevant locations. In this way, Concept 2 keeps the interaction simple and reduces the need for page navigation, while still allowing both scene activation and basic fine control when the label and button pairing is configured for that purpose.

5.3.5.4.3 Flexible button concept operation logic. The flexible button concept is not a complete interface concept in the same way as Concept 1 and Concept 2. It focuses on the physical button layout and how the interface can adapt when the number of needed controls changes. The basic idea is that the number of visible or usable buttons can be changed according to the installation need.

As shown in Figure 5.13, the same display area can be divided into different numbers of button zones. When fewer controls are needed, the interface can show larger areas with fewer functions, such as two large scene controls. When more controls are needed, the same area can be divided into three, four, or five smaller control zones. In this way, the interface can adapt to different numbers of scenes or functions without forcing all installations to use the same fixed button layout.

In use, the installer or configurator would select the button layout that matches the number of active scenes, channels, or functions. If fewer controls are needed, fewer buttons are exposed, and each label can use more space. If more controls are needed, the button surface can be configured to expose more control zones. This avoids showing inactive buttons to the user and reduces the chance that the user presses a button with no clear function.

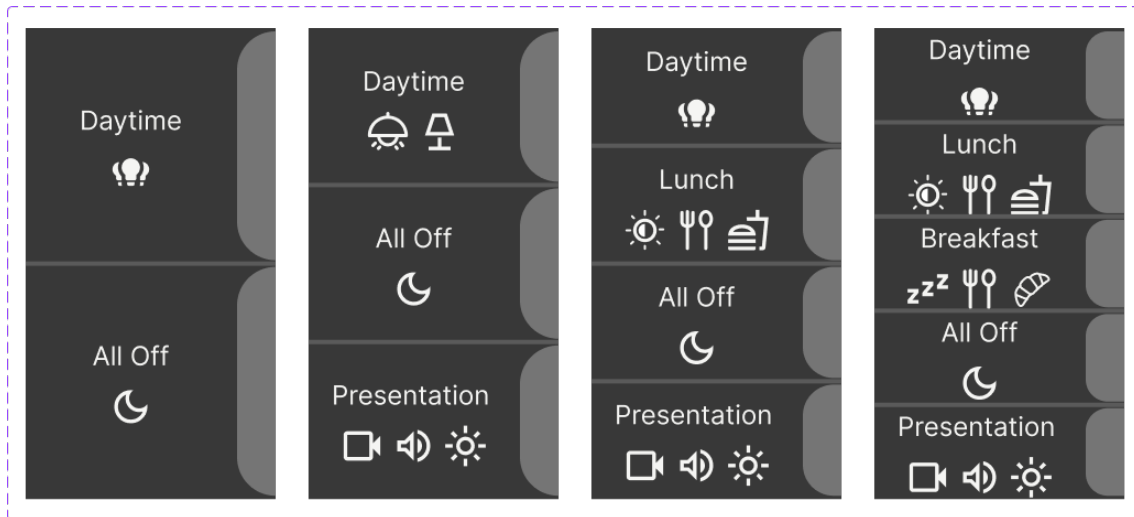


Figure 5.13: Flexible button concept showing different numbers of visible control zones

The flexible button concept therefore addresses the dead button problem from the hardware side. Instead of relying only on software labels, page switching, or multiple devices, it tries to make the physical button count match the actual control need. It was not developed as one of the main evaluated interface concepts, but it provided another possible direction for handling variation between installations.

5.3.5.5 Summary of Design Solutions

The three design outputs reflected different responses to the same design problem. Concept 1 prioritized contextual coverage and used page switching to support more functions within one control unit. Concept 2 prioritized compactness, first-use clarity, and lower manufacturing complexity by keeping each unit simpler and allowing multiple units when the control need increases. The flexible button concept focused on the physical issue of adapting button count to different installations.

Together, these solutions showed how the framework direction and commercial intervention shaped the design work in different ways. The framework helped define what the control unit needed to support, such as control scope, feedback, task hierarchy, scene control, and fine control. The commercial intervention then pushed the design toward understandability, readable labels, compactness, manufacturability, and ways to avoid dead or unclear buttons.

5.3.6 Design Evaluation

After the design solutions were developed, an evaluation was designed to compare the two main concepts. The flexible button concept was not included in the formal evaluation, because it was a physical product exploration rather than a complete interface concept.

5.3.6.1 Evaluation Design

The evaluation was designed around the same logic as the framework and the usability structure described in ISO 9241-11. According to ISO 9241-11, usability should be considered in relation to specified users, goals, tasks, resources, and environments, and can be evaluated through effectiveness, efficiency, and satisfaction (International Organization for Standardization, 2018). Based on this structure, the evaluation variables were organized around effectiveness, efficiency, and satisfaction, while the scenarios were used to keep the evaluation connected to different contexts of use.

The evaluation used selected scenarios from the earlier commercial scenario analysis. Because each test required scenario explanation, task execution, scoring, and follow-up comments, not all five scenarios were included. Therefore, two contexts were selected from the scenario matrix: hotel room and hotel lobby.

As shown in Figure 5.14, the five scenarios occupied different positions in the social interaction matrix. Hotel room and hotel lobby were selected because they created a clear contrast while still remaining relevant to the commercial project direction. The hotel room represented a more private, temporary, and lower social exposure situation, where the interaction could lean more toward personalizable and efficient use. The hotel lobby represented a more shared, visible, and operational situation, where the interaction needed to be more professional, predictable, and feedback-oriented.

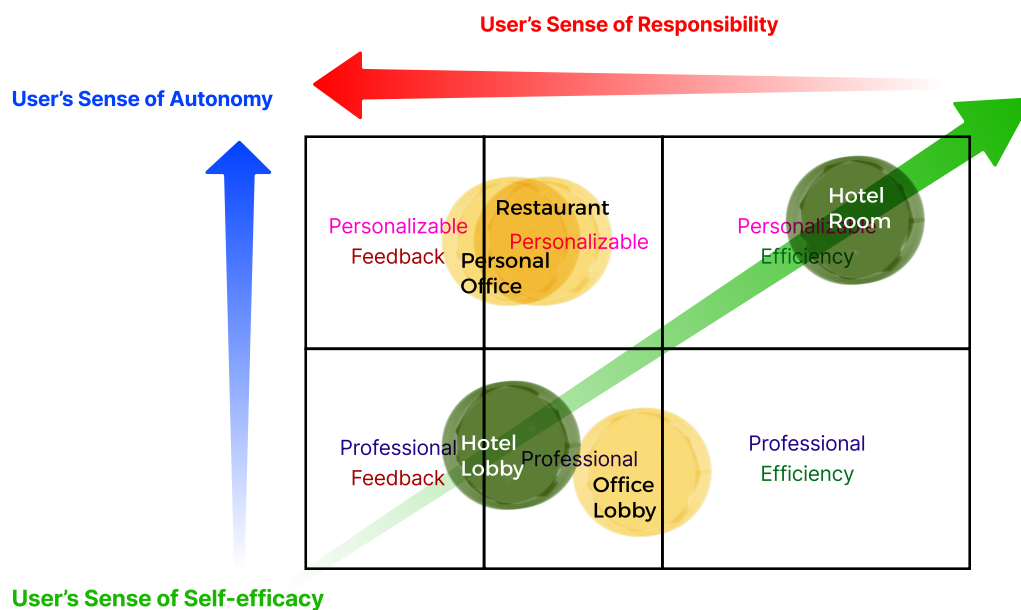


Figure 5.14: Summary scenario matrix used for selecting evaluation contexts

Within these two contexts, four role and task situations were used. The hotel room included a guest entering the room and cleaning staff preparing the room for the next guest. The hotel lobby included cleaning staff adjusting lighting for cleaning at night and front desk staff setting the lobby to a suitable morning condition. These tasks were selected because they created differences in privacy, task urgency, control responsibility, physical condition, and social exposure.

The evaluation variables were selected to match the main design questions. Since the concepts were intended to support physical interaction, clear feedback, fast understanding, and use across different contexts, the evaluation included both objective and perceived measures. The objective feedback sheet included single-hand operation possibility, success without error, consistency with expectation, understanding time, operation comfort, and hesitation time. These variables helped capture what happened during the task, rather than only what participants felt afterward.

The perceived attribute importance sheet was used before or during the scenario evaluation to understand what participants considered important in each situation. It included single-hand operation, achieving the task without error, expected functionality, short understanding time, trust in a short time, and comfort in executing the task. This was useful because different scenarios may not require the same qualities. For example, a hotel room guest with luggage may care more about quick understanding and single-hand operation, while a front desk worker in a lobby may care more about task success, trust, and functional fit.

Figure 5.15 summarizes how the evaluation variables were connected to the selected scenarios and concepts. It shows which usability aspects were considered in the evaluation and how the hotel room and hotel lobby scenarios were used to compare Concept 1 and Concept 2.

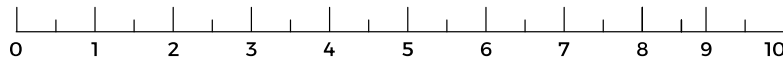
Usability Measures

Learning Curve	Object	Context	Task	Effectiveness measures		Efficiency measures		Satisfaction measures	
				Objective	Perceived	Objective	Perceived	Objective	Perceived
	• Concept 1	• Hotel Room	• Guest have just entered the hotel room and carrying luggage. It's the night time, the room is dark and the curtains are wide open. You want to quickly adjust the room feel comfortable.	• Single hand operation possibility • Success rate		• Understand ing time • Hesitation time		• Operation comfort • Functional satisfaction	
			• Guest has checked out. Clean Staff needs to clean and prepare for next guest.	• Single hand operation possibility • Success rate		• Understand ing time • Hesitation time		• Operation comfort • Functional satisfaction	
		• Hotel Lobby	• It is night time. The hotel lobby is still open, but guest traffic is low. The cleaning staff needs better visibility to inspect dust, stains, wet marks, litter, and the floor condition. However, a few guests are still sitting in the waiting area. After cleaning need to turn the lights to a suitable level.	• Single hand operation possibility • Success rate		• Understand ing time • Hesitation time		• Operation comfort • Functional satisfaction	
			• Front desk stuff are starting the morning shift. The lobby looks slightly dim while a lot of guests are here. Set the lobby to a suitable morning condition.	• Single hand operation possibility • Success rate		• Understand ing time • Hesitation time		• Operation comfort • Functional satisfaction	

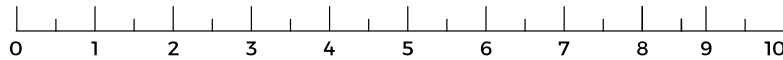
Figure 5.15: Usability measures and selected evaluation scenarios

Scaled Objective Feedback

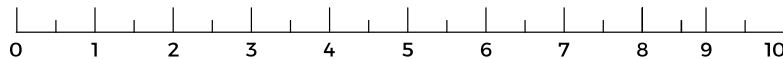
- Single hand operation possibility



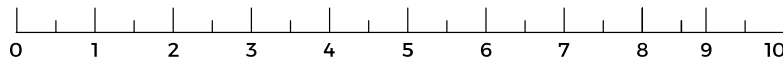
- Success without error



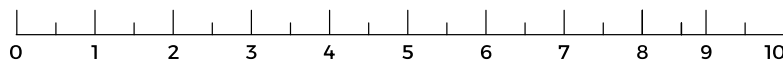
- The way the device functions is consistent with expectations.



- Understanding time



- Operation comfort



- Hesitation time



Figure 5.16: Scaled objective feedback sheet used in the evaluation

Figure 5.16 shows the scaled objective feedback sheet used after participants completed a task with the prototype. The sheet was used to record task-related performance and observed interaction qualities, such as single-hand operation possibility, success without error, consistency with expectation, understanding time, operation comfort, and hesitation time.

Figure 5.17 shows the perceived attribute importance sheet. This sheet was used to capture how important different interaction qualities were for a specific scenario before comparing how well the concepts supported those qualities.

Perceived Attributes Importance

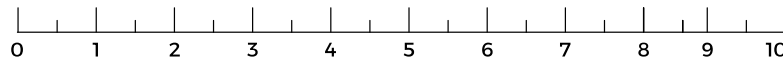
- Single hand operation



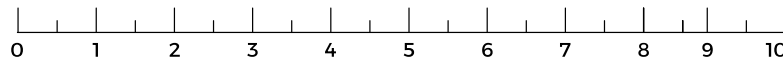
- Achieve the task without error



- The equipment provides functionality consistent with expectations.



- Understand the device in a short time



- Be able to trust the device in a short time



- Feel comfortable to execute the task



Figure 5.17: Perceived attributes importance sheet used in the evaluation

In this way, the evaluation was designed to compare the two concepts through both scenario needs and task performance. The importance ratings helped show which qualities mattered in each context, while the objective and perceived scores helped compare how well the concepts supported those qualities. This also made the evaluation a way to examine the design tradeoff between the framework-driven direction and the more commercially simplified direction.

5.3.6.2 Evaluation Explanation

The evaluation clarified the main design tradeoff. Concept 1 was more closely aligned with the framework's ambition to support contextual variation, but this also made the system more complex. Concept 2 was easier to understand and more realistic from a commercial product perspective, but it relied more on correct placement, naming, and system setup. In other words, the framework-driven direction supported broader contextual coverage, while the commercial direction supported clearer first time use and lower product complexity.

This finding was important for the design study. It showed that the framework can help generate a richer and more context-aware control structure, but that the output

of the framework still needs to be simplified when translated into a commercial product. The evaluation therefore did not invalidate either concept. Instead, it showed that both directions responded to different parts of the design problem.

The evaluation also suggested that neither Concept 1 nor Concept 2 should be treated as the final commercial direction without modification. A more feasible direction may be to use Concept 2 as the base and selectively add the necessary information and interaction support identified through the framework. This implication is discussed further in the next chapter.

The detailed evaluation process, data tables, and charts are presented in the Method, Results, and Appendix B. In this chapter, the evaluation is used mainly to explain how the design study explained the two concepts: Concept 1 as a stronger framework exploration, and Concept 2 as a more commercially feasible local control unit.

5.4 Summary

Overall, the Design chapter showed how the framework was translated from a research outcome into a practical design support tool, and how this tool was then applied in a commercial project context. The framework helped structure the analysis of physical context, social context, user roles, and task hierarchy. The commercial project then introduced additional constraints, including understandability, cost, product simplicity, competitor positioning, and the dead button problem.

The resulting design solutions therefore represented different balances between contextual coverage and commercial feasibility. Concept 1 explored a broader framework-based direction, Concept 2 explored a simpler and more market-oriented direction, and the flexible button concept explored a physical solution to variation in button needs. These design outcomes provided the basis for the evaluation and later discussion of how context factors can be translated into interaction requirements for indoor IoT control units.

6

Discussion

This chapter discusses the main findings of the project and reflects on how the results answer the research question. The discussion focuses on the role of the framework, the relation between user needs and design complexity, the tradeoff between contextual coverage and commercial feasibility, and the limitations of the research.

6.1 Main Findings

The main finding of this thesis is that context factors cannot be directly translated into interface features. Previous literature and standards already show that usability and interaction quality should be understood in relation to users, goals, tasks, and context of use (International Organization for Standardization, 2018, 2019). However, during this project it became clear that describing a context is not enough for design.

For this reason, the framework developed in this thesis introduced an intermediate translation layer. Physical factors were translated into ability impact, such as visual output, tactile output, audio input and output, and manual input. Social factors were translated into decision-making impact, including the user's sense of responsibility, autonomy, and self-efficacy. User and task factors were translated into task hierarchy, function priority, and functional depth. This made the framework more useful as a design support tool, because it helped move from context description toward design implication.

This finding also responds directly to the research question. The project identified several context of use factors that drive interaction requirements for indoor IoT control units. These factors are summarized in Table 6.1. They do not affect the interface in the same way. Some factors influence what users are physically able to do, some influence whether users feel allowed or confident to act, and some influence which functions should be available in the local control unit.

Table 6.1: Context of use factors that drive interaction requirements

Context factor	How it drives interaction requirements	Translation into control and feedback architecture
Physical environment factors	Affect what users can see, hear, touch, reach, and operate in a specific situation.	Translate into suitable modality, visual output, tactile output, audio input and output, and manual input requirements.
Social environment factors	Affect whether users feel responsible, allowed, confident, or socially comfortable when interacting.	Translate into interaction tendency, such as feedback, efficiency, professional predictability, or personalization.
User groups	Define who is expected to use the control unit, who is affected by it, and who should be prioritized.	Translate into primary, secondary, occasional, and affected user groups.
Control responsibility	Defines how much consequence or authority is connected to the user's action.	Translate into permission logic, confirmation, feedback strength, and protection of advanced functions.
Task hierarchy	Defines the complexity and depth of the tasks that the local control unit should support.	Translate into local functional depth, especially whether the unit should include Level 1, Level 2, Level 3, or Level 4 tasks.
Control scope	Defines what area, device, channel, or scene will be affected by an action.	Translate into readable labels, visible target mapping, feedforward, and system state display.
Frequency and consequence of tasks	Define whether a function should be fast and visible, or protected and placed deeper.	Translate into function priority, interface hierarchy, and whether a task should be handled locally or through the app ecosystem.

Within these factors, the environment-related part of the framework was further divided into physical and social factors. The detailed environment factors are summarized in Table 6.2. Physical factors were mainly used to understand ability impact, while social factors were mainly used to understand decision-making impact.

Table 6.2: Detailed environment factors used in the framework

Environment type	Factor group	Specific factors	Main interaction impact
Physical environment	Visual factors	Illumination, weather, installation place, viewing distance and angle, continuous visual attention, availability of eyesight.	Visual output.
Physical environment	Tactile factors	Contact location, vibration interference, temperature, gloves or covered hands.	Tactile output.
Physical environment	Auditory factors	Background noise, babble noise, sporadic noise, blocked ears, need to listen to the environment.	Audio input and output.
Physical environment	Reach and dexterity factors	Device location, number of hands available, available manual space, need for visual guidance, gloves or hand covering, wet or slippery conditions, temperature.	Manual input.
Social environment	Risk factors	Task involvement, obtrusiveness, protecting privacy.	Sense of responsibility and need for feedback or confirmation.
Social environment	Hierarchy clarity factors	Hierarchy, policy on device use, group dynamics.	Sense of autonomy and permission to act.
Social environment	Time factors	Pace and interaction urgency.	Need for efficiency, reduced steps, or stronger feedforward.
Social environment	Social exposure factors	People present, user's relationship to people, psychological predispositions and phenomena.	Sense of autonomy, self-efficacy, and social comfort during interaction.

Together, these tables show how the research question was answered.

Another important finding was that user needs cannot be treated as a direct list of interface functions. In the user study, participants often expressed a desire for more control, more feedback, more functions, and more flexibility. However, in the concept evaluation, a concept with broader function coverage was also perceived as more complex. This showed a difference between what users may ask for in an abstract discussion and what they can comfortably handle when the functions are placed in an actual interface. Therefore, user needs still require interpretation and prioritization before they become design features.

6.2 Design Tradeoffs

Several design tradeoffs were identified in the project.

1. One major tradeoff identified in the project was between contextual coverage and product simplicity. The framework helped identify many contextual demands, especially when the same control unit was expected to work across different commercial scenarios. From a framework perspective, this supported a richer control architecture. A control unit should show control scope, support scene control, allow fine control, provide feedback and feedforward, and separate simple operation from deeper configuration.

However, when these requirements were translated into a product concept, they also created complexity. Concept 1 showed that a framework-driven design can support more contextual variation, but may also require more learning. Users need to understand modes, pages, active areas, button labels, and the relation between scene control and channel control. This does not mean that the framework direction was wrong. Rather, it shows that the framework can reveal more design requirements than a single product should necessarily expose at once.

Concept 2 represented another side of the tradeoff. It limited the functional depth of each local unit, reduced page logic, and relied on clearer placement and naming. If more control was needed, multiple units could be installed instead of adding more layers into one device. This made Concept 2 more realistic as a commercial product direction, but also less flexible as a single interface. The evaluation therefore showed that the better design direction depends on what the product is expected to prioritize: broad contextual coverage or simple first time use.

2. A second tradeoff concerned user group prioritization and inclusiveness. The framework used primary, secondary, occasional, and affected user groups to help decide who the design should mainly support. This was useful because it prevented the design from assuming one universal user. It also helped define which users needed frequent access, which users needed limited access, and which users were mainly affected by the result of control.

At the same time, this method may also create a limitation. If the framework only focuses on the most frequent or most obvious user groups, less frequent

users may be overlooked. These may include visitors, older users, users with disabilities, emergency users, service workers, or people who rarely interact with the device but have important needs when they do. Therefore, user group prioritization should not be treated as a way to exclude uncommon users too early. It should be used to structure design priorities while still checking whether the resulting product remains inclusive enough for unexpected or low-frequency users.

3. A third tradeoff was between fixed physical input and dynamic function needs. Physical buttons are useful because they provide clear affordance, fast operation, and tactile confirmation. However, fixed buttons become problematic when the number of scenes, channels, or control targets changes between installations. This created the dead button problem. Concept 1 addressed it through page switching, Concept 2 addressed it by limiting each unit's function scope and allowing multiple units, while the flexible button concept explored whether the physical number of visible buttons could be changed. This showed that the dead button problem is not only an interface issue, but also a product architecture issue.

6.3 Physical Control and Visual Feedback

The project also showed the value of combining physical control with visual feedback. The framework analysis suggested that the design should avoid relying on one single modality. Commercial spaces may include noise, social exposure, poor visibility, one-hand use, or time pressure. Under these conditions, a pure touch screen interface may require too much visual attention and may create uncertainty about whether the screen is meant to be read, touched, or both.

Physical buttons became a suitable direction because they can support direct action and tactile confirmation. However, physical buttons alone were not sufficient. Many existing button-based products require users to remember what each button controls. This is especially problematic in shared commercial spaces, where users may be guests, cleaners, staff, or temporary users. These users cannot be expected to know the mapping in advance.

For this reason, visual feedback and readable labels became central to the design direction. The display was not treated as the main input surface. Instead, it was used to make the physical controls understandable. It could show button labels, control scope, active state, expected effect, and action result. This allowed the design to keep the advantages of physical input while addressing the problem of unclear button meaning.

Feedback and feedforward were also important because many commercial contexts require users to act with confidence. In shared or visible settings, users may hesitate if they do not know what will happen or whether their action has worked. The scenario matrix showed that most selected commercial scenarios leaned more toward professional, predictable, and feedback-oriented interaction than toward highly

personalizable interaction. This supported the decision to prioritize current state, expected effect, and result of action.

Personalization is still important. It may still be useful in private or repeated use contexts. However, for a local control unit intended to work across commercial spaces, professional predictability and clear feedback appear to be safer starting points. A professional and feedback-oriented interaction can still be used in more personal settings, while an overly personal interaction may not fit shared or formal settings.

6.4 Social Context and Control Responsibility

A key contribution of the framework was the attention given to social context. The project showed that users do not only ask whether they can operate a control unit. They also ask whether they are allowed to act, whether others will be affected, whether the action will be visible, and whether they will be responsible if something goes wrong.

This was visible in the user study. Guests were often reluctant to change environmental settings without permission. Office or lobby users could be physically close to a control point but still avoid using it because the control scope or social permission was unclear. Cleaning staff and front desk staff had more legitimate reasons to act, but their tasks also carried operational responsibility. These differences cannot be explained only through physical usability. They require attention to role, authority, responsibility, and social exposure.

The framework translated these social conditions into responsibility, autonomy, and self-efficacy. This made social context easier to use in design. For example, a user with low autonomy may need clearer permission cues or a more professional interaction style. A user with high responsibility may need stronger feedback, confirmation, and recovery. A user with low self-efficacy may need clearer feedforward and lower risk operation.

This suggests that smart control design should not treat shared spaces only as technical or spatial settings. A shared space is also a social environment. The same control action may feel acceptable in a private room, awkward in a lobby, and professionally risky in front of customers. Therefore, control interfaces in commercial environments should communicate not only what can be controlled, but also what is appropriate, who the control is for, and what the action will affect.

6.5 Framework Reflection

The framework developed in this thesis should be understood as an early design support framework, not as a fully validated predictive model. Its value is that it helps designers structure context analysis and avoid jumping directly from context labels to interface features. It also helps make design discussions more explicit. Instead of saying that a space is simply public or private, the designer can ask what physical abilities are affected, what social decision-making impacts are involved, which user groups matter, and which task levels should be included.

The design study showed that the framework can support concept development. Concept 1, which stayed closer to the framework logic, provided broader support for different scenarios, roles, and task levels. This suggests that the framework can help generate a richer control and feedback architecture. The user study also supported several parts of the framework, especially control scope, feedback, trust, role legitimacy, and task hierarchy.

However, the framework also has limitations.

1. It can increase complexity if all identified requirements are carried into the product without prioritization. This was visible in Concept 1. A framework can reveal what matters, but it does not automatically decide what should be simplified, hidden, moved to the app, or removed. The designer still needs to make product-level decisions.
2. The framework depends on the quality of scenario selection. If the selected scenarios are too narrow, the framework output may also become narrow. If the selected user groups are too limited, the design may overlook important but less frequent users. Therefore, the framework should be used iteratively. Scenario selection, user group definition, and task hierarchy should be reviewed as the project develops.
3. The scoring and interpretation logic in the framework is still qualitative. The framework helped organize analysis and concept development, but it was not tested as a quantitative model that can predict design performance. More studies are needed before it can be treated as a validated method.

6.6 Limitations

Several limitations should be considered when interpreting the results.

1. The first limitation concerns the scope of validation. The framework was informed by literature, supported by user study findings, applied in a design study, and partially examined through concept evaluation. However, this is still not enough to fully validate the framework. The number of participants was limited, and the concept evaluation only included selected scenarios. Therefore, the framework should be seen as a proposed design support tool rather than a fully proven model.
2. The concepts were tested through iPad-based prototypes. This made it possible to test interaction flow, layout, labels, page switching, and feedback states. However, it also created a mismatch with the intended product direction. The concepts were based on physical buttons with tactile feedback, but the evaluation was performed on a digital touch surface. This may have affected the results. Participants may have experienced extra confusion because the prototype looked like a screen and was operated like a touch display, even though the intended design was not a pure touch screen interface.

This limitation is important because tactile confirmation, physical affordance, button resistance, and hand movement could not be fully evaluated. As a

result, the iPad prototype may have underestimated the benefit of physical buttons and overestimated some confusion related to screen-based interaction. A physical prototype would be needed to evaluate the intended interaction more accurately.

3. This limitation concerns scenario coverage. Five commercial scenarios were analyzed, but only the hotel room and hotel lobby were included in the concept evaluation. These two scenarios were selected because they created a strong contrast, but they still cannot represent all commercial contexts. Office lobby, personal office, and restaurant contexts may create different interaction needs and should be tested in later work.
4. Another limitation concerns user diversity. The framework uses user group prioritization to support design decisions, but this may also reduce inclusiveness if less common users are excluded too early. The study did not include enough participants to fully represent differences in age, disability, technical confidence, cultural expectations, professional roles, or long-term use patterns. Future studies should include a wider range of users, especially users who may not be primary users but still need to interact with or be affected by the control unit.
5. The last limitation concerns commercial feasibility. The project considered cost, manufacturability, product size, and ecosystem fit, but it did not fully develop the electronics, production method, installation logic, or cost model. Therefore, the commercial conclusions should be understood as design-level reflections rather than engineering validation.

6.7 Practical Implications and Future Work

The most direct practical implication from the evaluation is that the most feasible commercial direction may not be either Concept 1 or Concept 2 in their current form. Concept 1 showed stronger stability across role, context, and goal changes, but also introduced more complexity. Concept 2 showed stronger first-use clarity and lower product complexity, but depended more on correct naming, placement, and configuration. Therefore, a more realistic direction would be to use Concept 2 as the base and add selected framework-driven elements where they are necessary.

This means that Concept 2 should not simply remain a minimal control unit. It should still include the information that the framework identified as essential, such as readable labels, clear control scope, current state, expected effect, and feedback after action. In other words, the commercial direction should not remove the framework logic, but compress it into a simpler product structure. This would allow the product to keep the advantages of Concept 2, such as compactness, lower complexity, and easier first time use, while reducing the main risks identified in the evaluation.

This also shows how the framework should be used in commercial design. The framework is not meant to make the product as complete as possible. Instead, it helps identify which information and interaction support should not be lost when the design is simplified. In this project, this suggests that a revised Concept 2 could

be the more feasible product direction, as long as it keeps the essential feedback, feedforward, and control scope information identified through the research.

The findings also suggest several broader practical implications for designing indoor IoT control units.

1. Designers should not start only from a list of functions. They should first understand the context of use, including physical conditions, social conditions, user groups, and task levels. Without this step, a control unit may become technically capable but unclear or inappropriate for its use situation.
2. A local control unit should not always try to include the whole smart system. The findings suggest that Level 1 and Level 2 tasks are more suitable for local physical control. These include on and off control, preset selection, scene activation, and specific value or area adjustment. More advanced tasks, such as scene configuration, routine setting, device hierarchy, access control, and maintenance, may be better handled through an app or another part of the ecosystem.
3. Physical controls should be made readable. Physical buttons can support fast and confident interaction, but they need visible labels, control scope, feedforward, and feedback. Otherwise, users may not understand what the buttons do, especially in shared or commercial spaces.
4. Design teams should be cautious when translating user requests into features. Users may ask for many forms of control when discussing smart systems, but a real interface with too many visible functions can become difficult to understand. The role of design is therefore not only to collect user needs, but also to structure and prioritize them.

Future work should focus on the following directions.

1. Future work should first test the concepts with a physical prototype. This would allow evaluation of tactile feedback, button feel, installation height, real viewing distance, and actual lighting conditions. It would also reduce the confusion caused by testing physical button concepts on an iPad.
2. Future work should also test the framework in more contexts. The office lobby, personal office, and restaurant scenarios should be evaluated, and additional contexts such as classrooms, healthcare spaces, or residential shared entrances could be included. This would help examine whether the framework remains useful beyond the scenarios used in this thesis.
3. Another direction is to further develop the flexible button concept. This idea responded to the dead button problem from the hardware side, but it still requires mechanical exploration, usability testing, and manufacturability assessment. It may be especially relevant for products that need to fit many different installations without creating inactive or unclear controls.
4. Finally, the framework itself should be refined through more design projects. It would be useful to see whether other designers can apply it consistently, whether the scoring logic needs to be simplified, and whether the framework can support decision-making without making the design process too heavy. In

this sense, the framework is not the final result of the topic, but a starting point for further work on context-driven interaction design for indoor IoT control units.

7

Conclusion

This thesis project developed a framework for translating context of use factors into interaction design guidance for indoor IoT control units. The work also applied the framework in a commercial design case, resulting in two main Push Display concepts and one additional flexible button concept.

The framework can therefore be considered the main contribution of the thesis. It helps structure the design process by translating context factors into ability impact, decision-making impact, task hierarchy, and design guidance. This makes it easier to move from a broad understanding of context toward more concrete decisions about modality, feedback, labels, function priority, and local control depth.

Due to the limited scope of the evaluation, the framework and concepts cannot be considered fully validated. The prototypes were tested on an iPad, which could not fully represent the tactile qualities and physical affordances of real buttons. More testing with physical prototypes, broader user groups, and additional indoor contexts would be needed before the concepts could be developed further.

Overall, the thesis suggests that context-driven design can support more understandable and appropriate indoor IoT control units. By translating context into interaction requirements, designers can make more deliberate decisions about what a local control unit should show, what it should control, and how much complexity it should include.

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A

Appendix A

This appendix contains the evaluation sheets used to apply the framework in scenario analysis. The sheets were used to analyze physical environment factors, social environment factors, and user and task factors before concept development and concept evaluation.

A.1 Physical Environment Factors Evaluation Sheet

Physical Environment Factors Evaluate			
Visual Factors			
Illumination		Ability to see/read and understand the texts, graphics	
Weather			
Typical Storage Places		Environmental movement trends	
Typical Viewing distance and angle			
If the needs are continuous?			
If the eyesight is available?			
Tactile Factors			
Typical storage location		Ability to feel and understand the tactile output if the device.	
Vibra "leak" from other devices			
Temperature		Acceptance of tactile output.	
Need to wear gloves			
Auditory Factors			
Level and spectrum of background noise		Ability to speak in the environment	
Babble noises		Ability of the device to recognize the user's speech	
Sporadic noises		Ability to hear and understand device output (speech or nonspeech audio)	
Something blocking the ears			
Needs to listen to the environment			
Reach and Dexterity			
Storage location of the device		Ability to use the hands (either or both) in the environment, for interacting	
Number of hands available for device operation		Ability to operate device accurately enough by using hands	
Available space for manual use		Ability to manually access device quickly enough	
Possibility for use the vision		Ability to see what to interact	
Rain, snow			
Temperature			

Figure A.1: Physical environment factors evaluation sheet

A.2 Social Environment Factors Evaluation Sheet

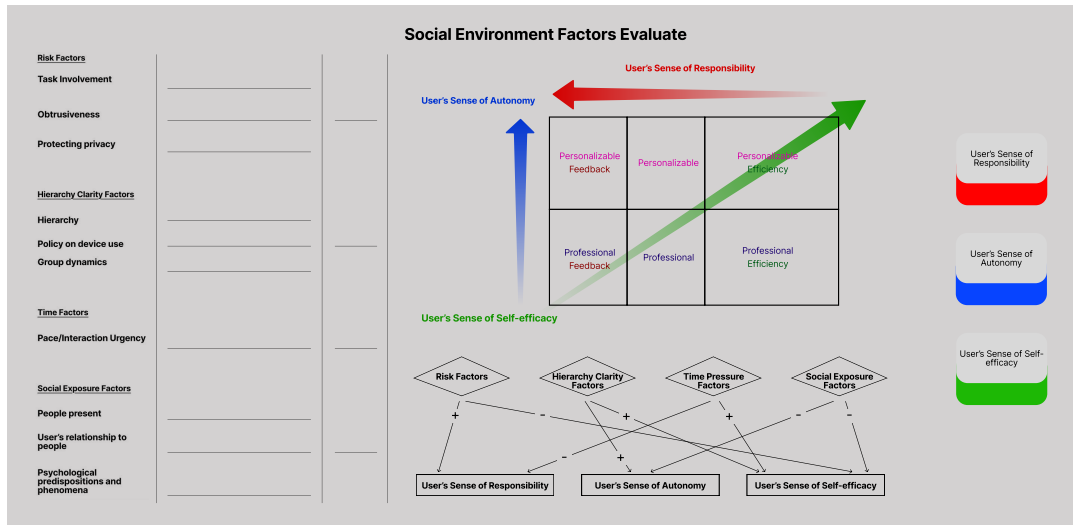


Figure A.2: Social environment factors evaluation sheet

A.3 User Group and Task Evaluation Sheet

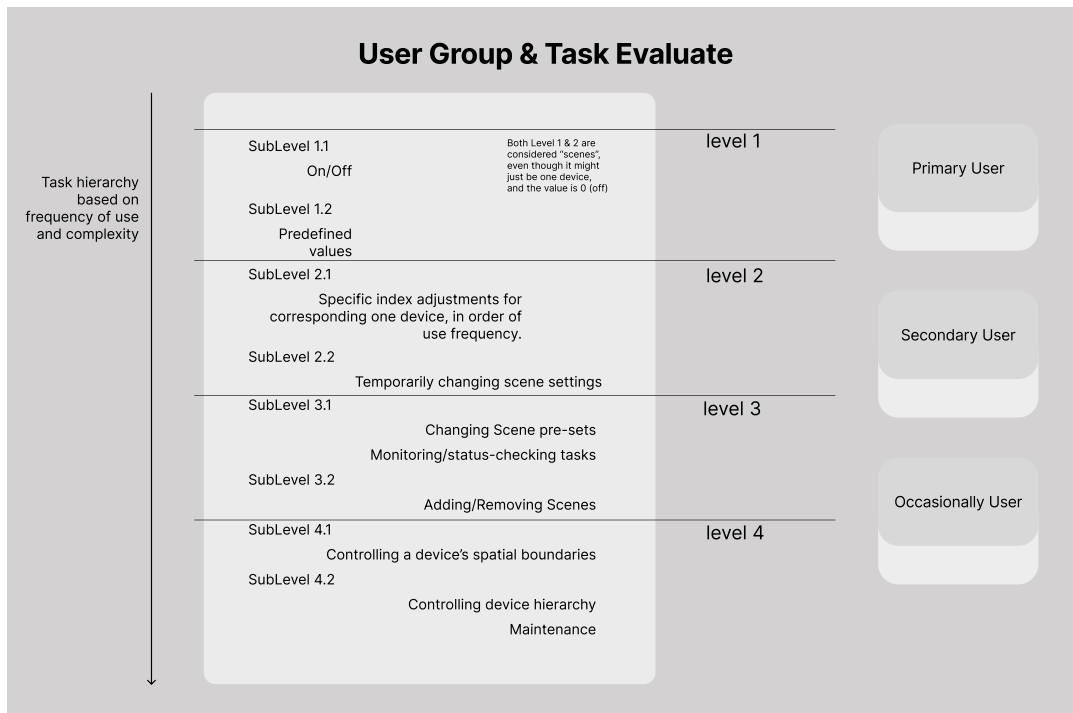


Figure A.3: User group and task evaluation sheet(Indoor Control Tasks as Task Hierarchy Example)

B

Appendix B

This appendix contains the supporting data from the concept evaluation. The material was converted from the final evaluation spreadsheet and is presented as editable LaTeX tables and inserted diagram images instead of inserted PDF pages. It includes the scenario setting, participant overview, calculation method, evaluation diagrams, raw evaluation scores, learning data, and the comparison between the two concepts.

B.1 Scenario Setting

Table B.1: Scenario codes used in the evaluation

Code	Context	Role	Scenario
T1	Hotel room	Guest	Guest arrival
T2	Hotel room	Clean staff	Check out turnover cleaning
T3	Hotel lobby	Clean staff	Night low traffic cleaning visibility
T4	Hotel lobby	Front desk staff	Morning lobby condition

B.2 Participants

Table B.2: Participants in the concept evaluation

Participant	Age	Gender	Concept tested
1	24	Male	Concept 1 and Concept 2
2	28	Male	Concept 1 and Concept 2
3	32	Male	Concept 1
4	28	Female	Concept 1
5	24	Female	Concept 1
6	24	Male	Concept 2
7	40–50	Male	Concept 2
8	54	Female	Concept 2

B.3 Calculation Method

The following formula images were included in the original evaluation spreadsheet. They show how weighted dimension scores, participant total scores, and index scores were calculated.

$$\text{Weighted Dimension Score} = \frac{\text{Dimension Weight}}{\text{Total Task Weight}} \times \text{Participant Rating}$$

Figure B.1: Formula for weighted dimension score

$$\text{Participant Total Score} = \sum \text{Weighted Dimension Scores}$$

Figure B.2: Formula for participant total score

$$\text{Index Score} = \frac{\sum \text{Weighted Dimension Scores of All Participants}}{\text{Number of Participants}}$$

Figure B.3: Formula for index score

B.4 Evaluation Diagrams

This section contains the nine diagrams generated from the final evaluation data. The diagrams show learning patterns, task average scores, and comparison between Concept 1 and Concept 2.

B.4.1 Concept 1 Diagrams

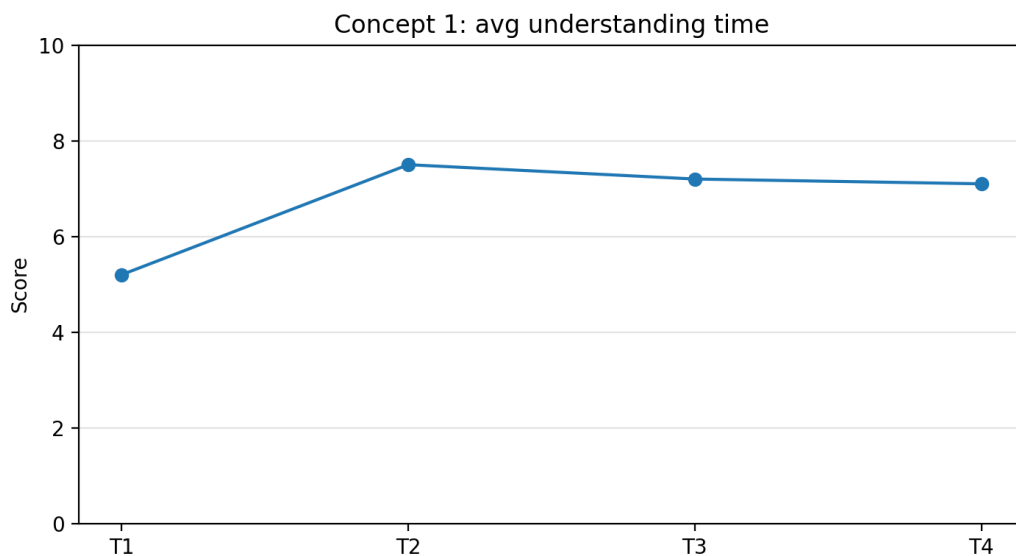


Figure B.4: Concept 1 average understanding time

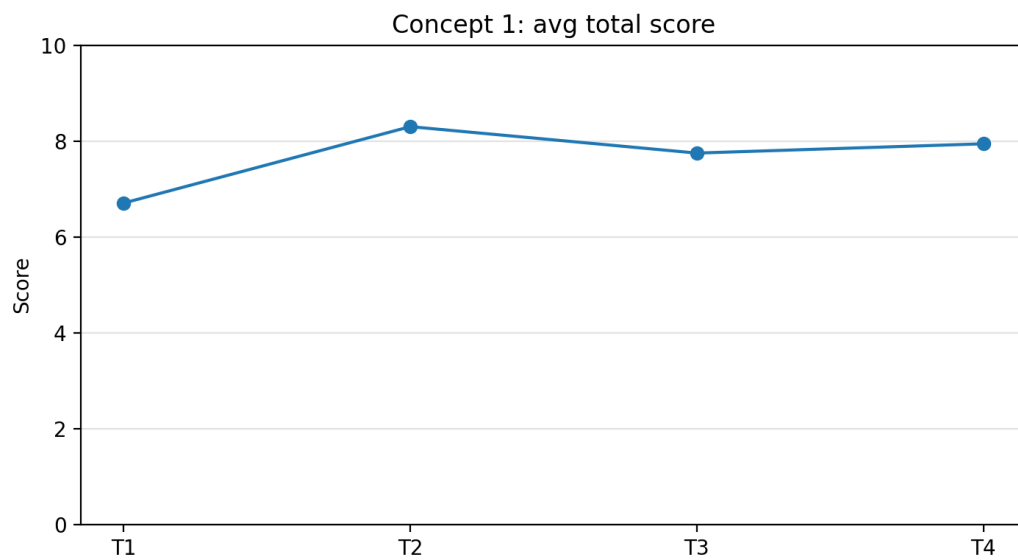


Figure B.5: Concept 1 average total score

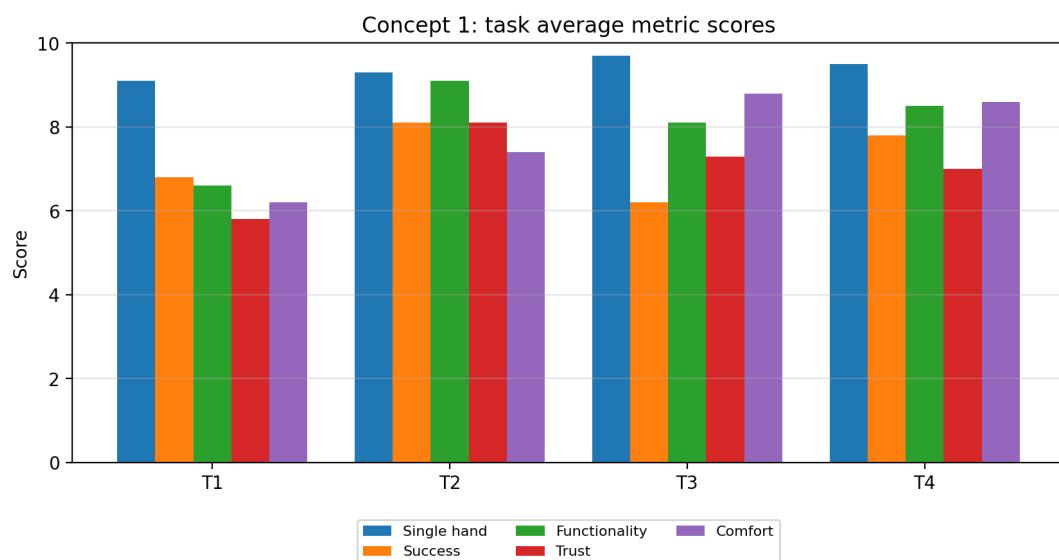


Figure B.6: Concept 1 task average metric scores

B.4.2 Concept 2 Diagrams

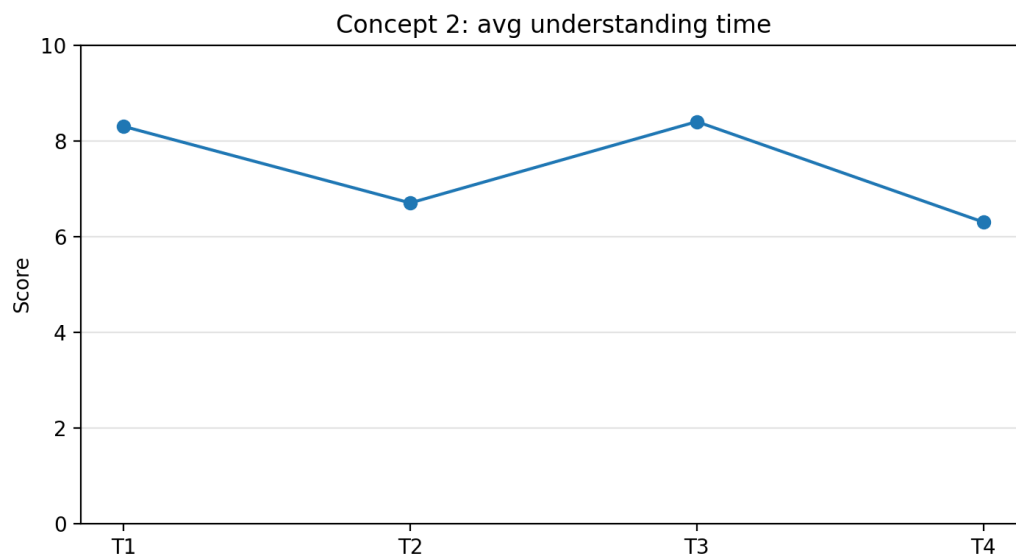


Figure B.7: Concept 2 average understanding time

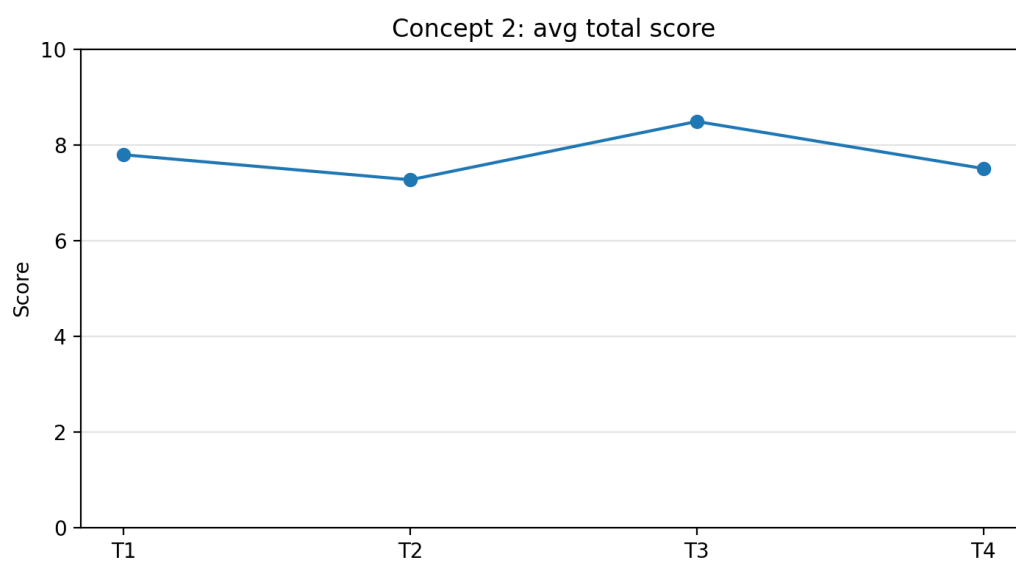


Figure B.8: Concept 2 average total score

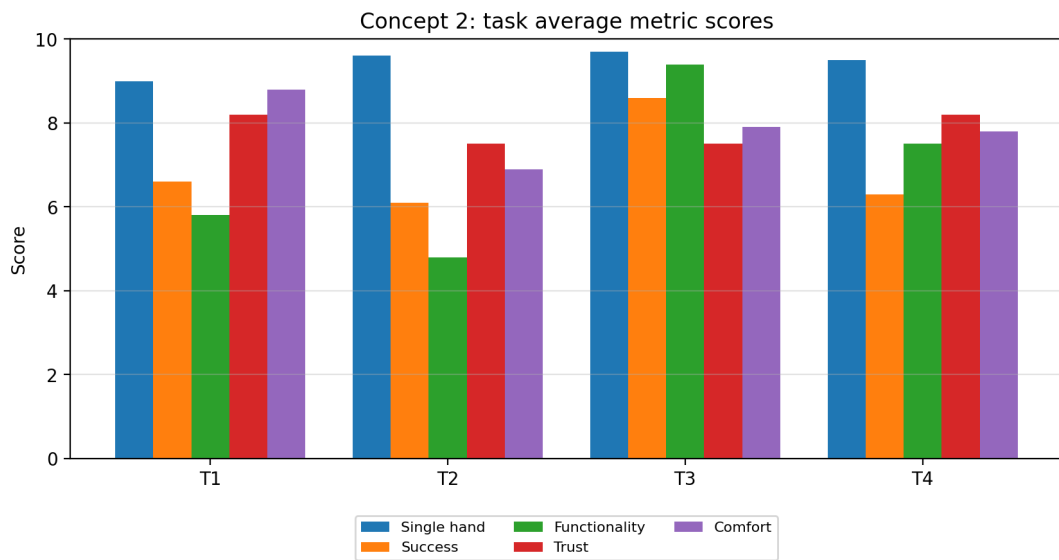


Figure B.9: Concept 2 task average metric scores

B.4.3 Comparison Diagrams

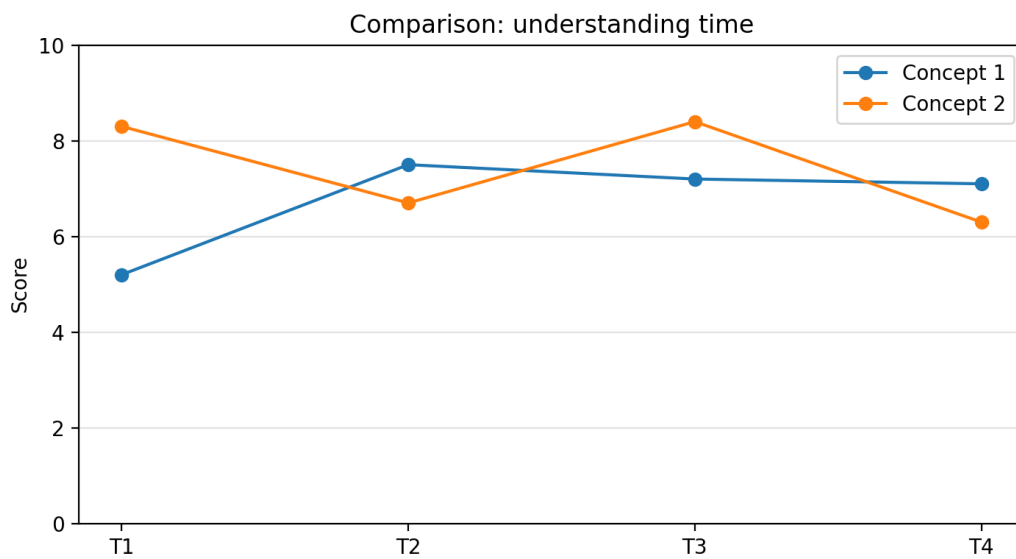


Figure B.10: Comparison of average understanding time

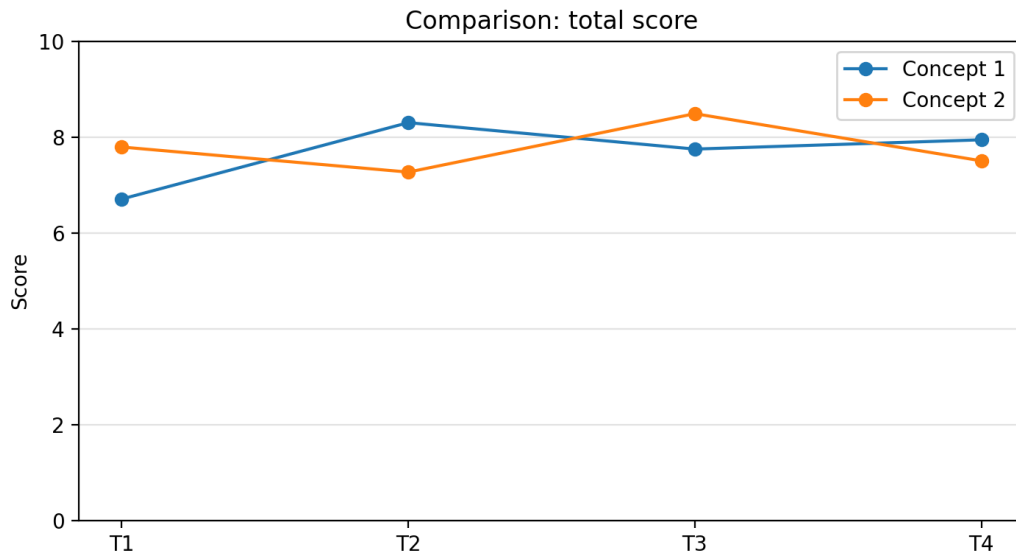


Figure B.11: Comparison of average total score

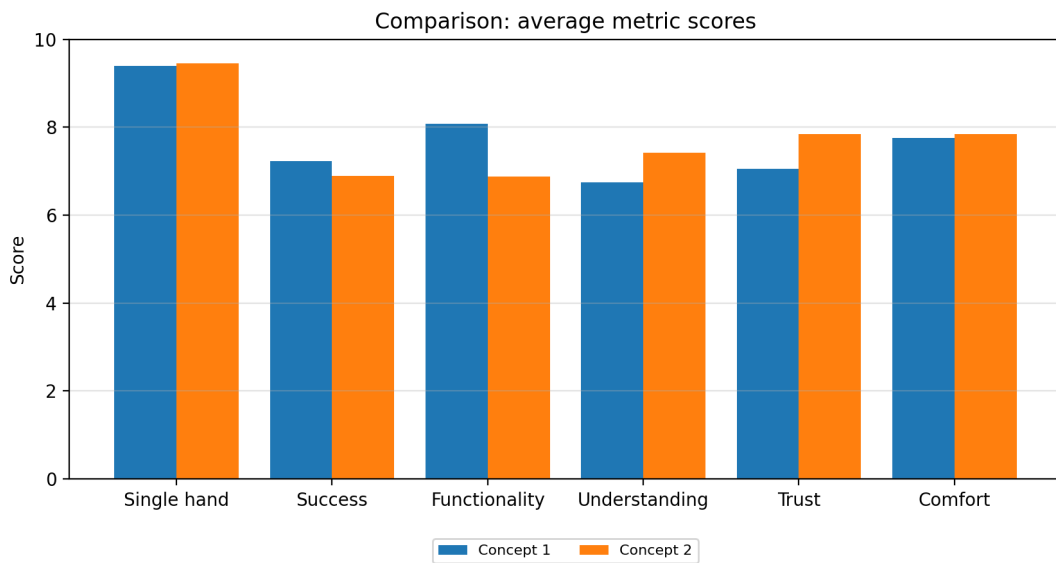


Figure B.12: Comparison of average metric scores

B.5 Scenario Scores

Table B.3: Scenario score comparison between Concept 1 and Concept 2

Context	Role	C1 score	C1 context avg.	C2 score	C2 context avg.
Hotel Room	Primary User: Guest	6.71	7.50	7.79	7.53
Hotel Room	Secondary User: Clean Staff	8.30		7.27	
Hotel Lobby	Secondary User: Clean Staff	7.75	7.84	8.49	8.00
Hotel Lobby	Primary User: Front Desk	7.94		7.50	
Average score		7.67		7.76	

B.6 Index Importance

The index importance table shows how participants rated the importance of each evaluation index in different contexts and roles.

Table B.4: Index importance by context and role

Context	Role	Single-hand	Task without error	Functionality	Understanding	Trust	Comfort
Hotel Room	Primary User: Guest	8.12	7.12	6.19	7	6.38	7.44
Hotel Room	Secondary User: Clean Staff	8.19	6.38	5.75	6.69	5.44	5.44
Hotel Lobby	Secondary User: Clean Staff	7.38	8.81	7.56	7.38	8.31	7.12
Hotel Lobby	Primary User: Front Desk	7.06	9	8.50	8.69	8.25	6.81

Table B.5: Average index importance by context

Context	Single-hand	Task without error	Functionality	Understanding	Trust	Comfort
Hotel Room	8.16	6.75	5.97	6.84	5.91	6.44
Hotel Lobby	7.22	8.91	8.03	8.03	8.28	6.97

B.7 Raw Evaluation Scores

The following tables show the measured score for each participant and task. The values are the direct scores used in the spreadsheet before the later comparison. The total score is the weighted total score for each participant and task.

Table B.6: Concept 1 raw evaluation scores

P	Task	Single-hand	Success	Functionality	Understanding time	Hesitation	Comfort	Total
1	T1	9.50	9	9	7	9	8	8.51
1	T2	9.50	9.50	9.50	9.50	9	9	9.39
1	T3	9.50	9	9.50	9	8.50	9	9.03
1	T4	9.50	9	9.50	9	9	9	9.13
2	T1	9	8	8	8	7	7	7.86
2	T2	9	7	8	6	7.50	7	7.55
2	T3	9	4	9	4	2	8	5.68
2	T4	9	5	6	2.50	2	7	4.87
3	T1	9	3	3	2	1	3	3.69
3	T2	10	10	10	6	7	5	8.15
3	T3	10	2	2	9	10	10	6.67
3	T4	9	9	9	9	9	9	9
4	T1	8	8	7	2	4	5	5.85
4	T2	8	8	10	8	9	8	8.41
4	T3	10	10	10	5	7	8	8.54
4	T4	10	10	10	7	7	10	8.83
5	T1	10	6	6	7	8	8	7.62
5	T2	10	6	8	8	8	8	8
5	T3	10	6	10	9	9	9	8.82
5	T4	10	6	8	8	8	8	7.88

Table B.7: Concept 2 raw evaluation scores

P	Task	Single-hand	Success	Functionality	Understanding time	Hesitation	Comfort	Total
1	T1	9	8	9	9	8	9	8.67
1	T2	9	9.50	9	9.50	9.50	9.50	9.30
1	T3	9.50	9	9	8	7.50	8.50	8.54
1	T4	9.50	6.50	8.50	6.50	6	6	6.90
2	T1	9	5	5	9.50	9	10	8.49
2	T2	9	3	1	1	0	1	3.12
2	T3	9	9	9	9	9	9	9
2	T4	9	2	2	1	9	9	4.85
3	T1	7	5	3	9	8	8	5.79
3	T2	10	3	2	8	10	10	7.24
3	T3	10	10	10	9	3	3	7.12
3	T4	9	10	10	9	10	9	9.51
4	T1	10	10	6	6	7	8	8.17
4	T2	10	10	3	6	8	5	8.04
4	T3	10	10	10	7	9	10	9.32
4	T4	10	8	8	6	7	6	7.79
5	T1	10	5	6	8	9	9	7.82
5	T2	10	5	9	9	10	9	8.63
5	T3	10	5	9	9	9	9	8.46
5	T4	10	5	9	9	9	9	8.47

Table B.8: Index score comparison from raw evaluation sheets

Concept	Single-hand	Success	Functionality	Understanding	Trust	Comfort
Concept 1	9.40	7.22	8.07	6.75	7.05	7.75
Concept 2	9.45	6.90	6.88	7.42	7.85	7.85

Table B.9: Concept 1 learning summary

Avg. understanding	Avg. total score	Early avg. UT	Later avg. UT	Learning change
6.75	7.67	6.35	7.15	0.80

Table B.10: Concept 1 task average scores

Task	Scenario	Avg. understanding	Avg. total	Single-hand	Success	Functionality	Trust	Comfort
1	Guest arrival	5.20	6.71	9.10	6.80	6.60	5.80	6.20
2	Check-out turnover cleaning	7.50	8.30	9.30	8.10	9.10	8.10	7.40
3	Night off-peak cleaning visibility	7.20	7.75	9.70	6.20	8.10	7.30	8.80
4	Morning lobby condition	7.10	7.94	9.50	7.80	8.50	7	8.60

Table B.11: Concept 2 task average scores

Task	Scenario	Avg. understanding	Avg. total	Single-hand	Success	Functionality	Trust	Comfort
1	Guest arrival	8.30	7.79	9	6.60	5.80	8.20	8.80
2	Check-out turnover cleaning	6.70	7.27	9.60	6.10	4.80	7.50	6.90
3	Night off-peak cleaning visibility	8.40	8.49	9.70	8.60	9.40	7.50	7.90
4	Morning lobby condition	6.30	7.50	9.50	6.30	7.50	8.20	7.80

Table B.12: Concept 1 understanding time by participant

Participant	T1	T2	T3	T4	T4 minus T1
P1	7	9.50	9	9	2
P2	8	6	4	2.50	-5.50
P3	2	6	9	9	7
P4	2	8	5	7	5
P5	7	8	9	8	1

Table B.13: Concept 2 understanding time by participant

Participant	T1	T2	T3	T4	T4 minus T1
P1	9	9.50	8	6.50	-2.50
P2	9.50	1	9	1	-8.50
P3	9	8	9	9	0
P4	6	6	7	6	0
P5	8	9	9	9	1

B.8 Learning Indicators

Table B.14: Concept 1 learning indicators

Indicator	Value	Direction
Learning change (Later - Early)	0.80	Positive learning effect
Role Switch effect (T2 - T1)	2.30	Positive learning effect + Role switch effect is positive
Context switch effect (T3 - T2)	-0.30	Minor context switch cost
Role/goal switch effect (T4 - T3)	-0.10	Minor role/goal switch cost

Table B.15: Concept 2 learning indicators

Indicator	Value	Direction
Learning change (Later - Early)	-0.15	Learning effect is not obvious
Role Switch effect (T2 - T1)	-1.60	High role switch cost
Context switch effect (T3 - T2)	1.70	Context switch effect is positive
Role/goal switch effect (T4 - T3)	-2.10	High role switch cost

B.9 Concept Comparison

Table B.16: Task average comparison between Concept 1 and Concept 2

Task	Scenario	C1 understanding	C2 understanding	Delta understanding	C1 total	C2 total	Delta total
1	Guest arrival	5.20	8.30	3.10	6.71	7.79	1.09
2	Check-out turnover cleaning	7.50	6.70	-0.80	8.30	7.27	-1.03
3	Night off-peak cleaning visibility	7.20	8.40	1.20	7.75	8.49	0.74
4	Morning lobby condition	7.10	6.30	-0.80	7.94	7.50	-0.44

Table B.17: Learning and transition comparison between Concept 1 and Concept 2

Indicator	C1 value	C2 value
Early avg understanding time (T1&T2)	6.35	7.50
Later avg understanding time (T3&T4)	7.15	7.35
Learning change (Later - Early)	0.80	-0.15
Role Switch effect (T2 - T1)	2.30	-1.60
Context switch effect (T3 - T2)	-0.30	1.70
Role/goal switch effect (T4 - T3)	-0.10	-2.10
understanding–performance alignment	0.97	0.81

Table B.18: Average metric comparison between Concept 1 and Concept 2

Metric	C1 avg.	C2 avg.	Delta C2 minus C1
Total Score	7.67	7.76	0.09
Single-hand Score	9.40	9.45	0.05
Success Score	7.22	6.90	-0.32
Functionality Score	8.07	6.88	-1.20
Understanding Score	6.75	7.42	0.67
Trust Score	7.05	7.85	0.80
Comfort Score	7.75	7.85	0.10

C

Appendix C

This appendix contains the main user study material used in the analysis. It includes a summary of the survey, field study notes with image placeholders, interview summaries, and a summary of the scenario enactment. Since the full interview and scenario enactment transcripts were very long, summarized versions are included.

C.1 Survey Summary

The survey was used to collect broader information about people's experience with smart control systems in home and non-home environments. In total, 51 responses were collected. The survey focused on previous experience with smart control systems, commonly used control methods, preferred interaction styles, perceived difficulties, and differences between private and shared use contexts.

Results of the survey were used as an early overview of recurring user needs and as supporting material for the later field studies, interviews, and scenario enactment. The main value of the survey was to show which issues appeared repeatedly across a broader group of respondents, such as the need for clear feedback, simple control for frequent tasks, understandable system status, and low-effort interaction.

The survey also helped confirm that smart control needs differ between private and shared contexts. In private contexts, users were more willing to adjust settings according to personal preference. In shared or public contexts, users were more cautious, especially when the control scope, permission, or effect on others was unclear. These findings supported the later focus on role, control scope, feedback, trust, and social acceptability.

C.2 Field Study Notes

The following notes were taken during field observations of smart control points in public and semi-public campus environments. The original text notes are included after the image placeholders.

C.2.1 Field Study Images



Figure C.1: Field study image 1



Figure C.2: Field study image 2



Figure C.3: Field study image 3



Figure C.4: Field study image 4



Figure C.5: Field study image 5



Figure C.6: Field study image 6

C.2.2 Original Field Study Notes

Inside of the “company” building at the end of the SB/Fuse corridor:
Open to students, and from the universities side it was designed to connect the university
→ to students at a higher rate, as a part of Johanneberg Science Park.
However, the environment felt unwelcoming to students, where people in meeting rooms
→ look outside to see who was “drifting” around in the area.
There were QR codes to scan to book meeting rooms and a “podcast studio”, however, one
→ of the qr codes that were scanned that lead to access to a “lounge” gave us a 404 on
→ opening.

One “scene switcher” was observed, positioned near the restaurant area, where queues
→ form during lunchtimes. It was placed on a wall, in a bookshelf with newspapers that
→ seemed to be there for people to read.

A paper note under both scene switchers were labeled with “morning/breakfast”, “lunch”,
→ “evening”, “cleaning”. These settings were clearly labeled for the facilitators of the
→ space/the workers at the restaurant for the light levels in the space. The positioning
→ of it was however placed at a high guest-passthrough area.

If a guest reads the labels, it is clear that they should not control these settings.

No information in the labels mentioned the “sphere of influence”.

From this we can draw the conclusion that interaction from guests with this device,
→ although no special permissions are needed to operate it, are highly discouraged.

Inside the new campus building:

No controls of any settings were allowed to be manipulated by the spaces inhabitants. The
→ few places that looked like interaction points, were in reality wall outlets.

even on personal desks with light strips to light up those desks were lighting controls

- present. This signals partly a lack of trust in the occupants, where they are removed
- from controlling their environment in any sense. There is a clear non-present
- authority that controls the environment and does not let any level of control be
- passed down to occupants.

In the “fuse” study booth area:

Two forms of lighting controls were observed, placed on either side of the room. No

- labeling were present, but when tested, they changed the light intensity of two long
- light strips that covered the whole space of approximately 7*25 meters.

The manipulation of the switches affected all parts of the room, with lesser control on the

- individual booths. With approximately 20 students present in a room, a test was
- conducted where we turned off the lights in the “general” space, which also affected
- the total light intensity of the booths where students were studying. This was
- conducted to see if students reacted to the environmental shift, and if they would act
- upon in to change it back to a “comfortable level”.

Several students in the space reacted to the change, looking at each other, with murmurs

- or giggles at the change, but no one present at the time, or in the following 20
- minutes either looked, or f

Some students that arrived to a dark booth after the lights were turned down was heard

- saying “is there a light switch here or anything?”. With one of them walking away
- from the booth to find the lighting control, however they did not find it.

After 25 minutes of the lights being turned down incrementally, with them being turned

- off for 15 minutes, the group arriving after lights were off, they eventually found the
- scene control, this led to the lights being turned up, followed by them being lowered,
- followed by them being turned off, followed by them being turned to full brightness.

After asking around, it was found that an employee at the facility was the person who

- turned on the lights. This is interesting as even a person employed to the facilities,
- who frequents the space and has a certain level of authority, themselves performed at
- least two errors to perform the action they intended.

It's important to note in this scenario that the students aren't guests, they're the intended

- occupants.

Note from Xu:

Place: Chalmers SB building, Fuse lobby

Potential "Control": Lighting for entire lobby

Hierarchy: Visitor, Frequent Student, Cleaning worker, office worker.

Visitor: 22

Frequent Student: 9

Cleaning Worker: 2

Office worker: 5

All visitors just walked through the lobby. The 15th visitor stood in the dark lobby for
→ around 5 mins using a telephone.

The 3rd to 6th students are a group. They ignored the change at first, after around 20
→ mins, one student asked: Is the light turned off? And tried looking for the lighting
→ button for a very short time, which is around only 5 seconds.

The 8th and 9th students are a group. They found the lighting had been turned off and
→ reacted immediately with WTF. But did nothing.

There were 2 cleaning workers passing through, but none of them even noticed the change
→ of light.

There were 5 office workers passing through. The 3rd worker noticed the change at first,
→ but he didn't do any adjusting. He went back the second time and turned the light
→ back on. Noticeably, he made the mistake of pushing the wrong buttons twice.

Summarize

The old method, which categories the segmentations into four parts as public owned and
→ operated, public owned and private operated, private owned and public operated,
→ private owned and operated, is not suitable for the project. We think the
→ segmentation of public, semi-public and private is more suitable.

Public places (Public lobby at Campus building, Library, Hotel lobby, Science Park lobby)
→ offer almost zero "control" to the visitors, even the workers there. They are rather
→ automatically controlled or controlled by a specific role who works there but at the
→ same time not all the workers. The control panels are usually present in a hidden way
→ - rather hide them in a room/box with limited access, or make the position
→ unreachable/unnoticeable. Or there is a lock for the device.

Semi-public places (Fuse lobby, Library Workshop, Office) offer limited control options
→ with control panels that are reachable/noticeable. But the social norm/factors play a
→ huge role here. Which could depend on situations like different time periods and
→ people present/impacted. Which also significantly impacts user's willingness to use
→ the devices. Noticeably, the higher the role of the person in the specific organization,
→ the less social factor burden they have.

C.3 Interview Summaries

This section summarizes the four interviews used in the user study. The summaries keep the main content used for analysis, including user roles, control habits, trust, feedback, task access, and social use conditions.

C.3.1 Interview 1 Summary

Interview 1 focused on smart control use in a family home. The participant described a household where smart functions were mainly used for lighting, music, and energy-related control. The participant made a clear distinction between household members and guests. Household members could access more functions, while guests were only expected to use simple controls such as lights on or off.

A recurring point was that direct physical feedback was trusted more than hidden system responses. Physical buttons and remote controls felt reliable because the user could feel the action and immediately see whether the light changed. App-based control felt less reliable when the system response was delayed or when it was unclear whether the correct command had been received.

The interview also showed that too many options can create uncertainty. The participant preferred simple mode selection and direct control rather than interfaces with many buttons or settings. In shared situations, the participant would usually check whether other people were present before changing a shared setting. This supported the need for clear control scope, visible feedback, and simple access to frequent functions.

C.3.2 Interview 2 Summary

Interview 2 focused on smart control use in a single-person apartment. The participant used smart lights, smart speakers, and a robot vacuum. Voice control was the main method for everyday control because it allowed the user to act while doing other things. It was mainly used for lights, brightness, and music.

The participant valued immediate and visible results. For lighting, trust was easy to build because the environment changed directly after the command. For music control, the participant experienced more friction because selecting specific content required more steps in an app. When voice control failed, the participant often used a physical button or app as a fallback.

The robot vacuum was mentioned as a positive example because the app showed the map and the route clearly. This made the system behavior easier to understand. Overall, this interview supported the need for visible system state, direct feedback, and recovery options when the first interaction method fails.

C.3.3 Interview 3 Summary

Interview 3 focused on a family house with more advanced smart home systems, including lighting, alarm, solar panels, and battery systems. The participant acted as the main device manager and had responsibility for setup, maintenance, and system reliability.

Routine lighting functions were mostly automated and expected to work in the background. More complex energy and battery settings required occasional monitoring and adjustment. The participant relied on physical indicators and system state information to confirm that the system was behaving correctly.

One important example involved cleaning staff. The lighting schedule was automatic, but cleaners sometimes manually changed the light state, which later caused unexpected lighting conditions for the household. This showed that temporary users can have legitimate needs, but their actions may conflict with automation if the system does not explain current state and future behavior.

This interview supported the need for different task levels. Basic control should remain easy to access, while system configuration, energy strategy, alarm codes, and maintenance tasks should remain deeper or limited to responsible users.

C.3.4 Interview 4 Summary

Interview 4 focused on a shared apartment using voice assistants, smart speakers, and smart lights. The participant had set up most of the system, while the partner mainly used it for simpler actions such as turning lights on and off.

Voice control was used frequently and was valued because it could be fast and hands-free. Spoken confirmation from the assistant was also helpful because it told the user what had been done. However, voice control also created social and practical problems. Repeating a failed command could feel embarrassing, and several voice input points in the apartment sometimes made the system misunderstand the intended control scope.

The participant also discussed guests and temporary caretakers. Guests should be able to use basic functions such as lights, music, or temperature, but routines and automation settings should remain limited to the homeowner or administrator. This supported a layered structure where simple actions are available to more users, while permanent changes are protected.

C.4 Scenario Enactment Summary

The scenario enactment explored how user roles, social setting, and responsibility affect smart environmental control. The scenarios were based on home and office situations and asked participants to discuss how they would act when lighting, temperature, blinds, or other environmental settings needed to be changed.

C.4.1 Home Scenario

In the home scenario, participants discussed roles such as host, resident, guest, and older or younger family member. A repeated finding was that guests were reluctant to directly change the environment without permission. Even when a control point was physically reachable, using it could feel intrusive if the guest had not been invited to act.

The host had more responsibility and more freedom to use the system. However, the host also carried social risk if the system failed in front of guests. Voice control could feel convenient and sometimes impressive, but it could also become embarrassing when commands failed or had to be repeated. In that case, a physical control or phone app could feel safer.

The home scenario showed that permission is not only technical. A guest may become willing to act if the host directly asks them to use the control. This supported the importance of role legitimacy, permission cues, and simple controls for temporary users.

C.4.2 Office Scenario

In the office scenario, participants discussed roles such as meeting organizer, colleague, chief, and external client. The situation involved adjusting blinds or lighting for a presentation while other people were watching.

This scenario showed that smart control in a workplace can become connected to professionalism. The meeting organizer was expected to solve the issue quickly and without disturbing the meeting. A confusing or slow control interface could make the organizer appear unprepared. In this setting, users needed fast, clear, and predictable interaction.

Compared with the home scenario, the office setting made role expectations stronger and made mistakes more socially visible. This supported the need for clear control scope, professional interaction tone, reliable feedback, and low-risk recovery.

C.4.3 Main Points from the Scenario Enactment

The scenario enactment showed that smart control use is strongly affected by social context. Users may hesitate not because the interface is difficult, but because they are unsure whether they are allowed to act, whether others will be affected, or whether a mistake will be visible. The findings supported the framework's focus

on responsibility, autonomy, self-efficacy, role clarity, control scope, feedback, and recovery.

D

Appendix D

This appendix contains the scenario analysis sheets used in the commercial project design study. The five scenarios were analyzed through the framework before concept development. The task summary and user personas sheet was used to support the interpretation of user groups, task levels, and functional depth across the selected commercial scenarios.

D.1 Tasks Summary and User Personas

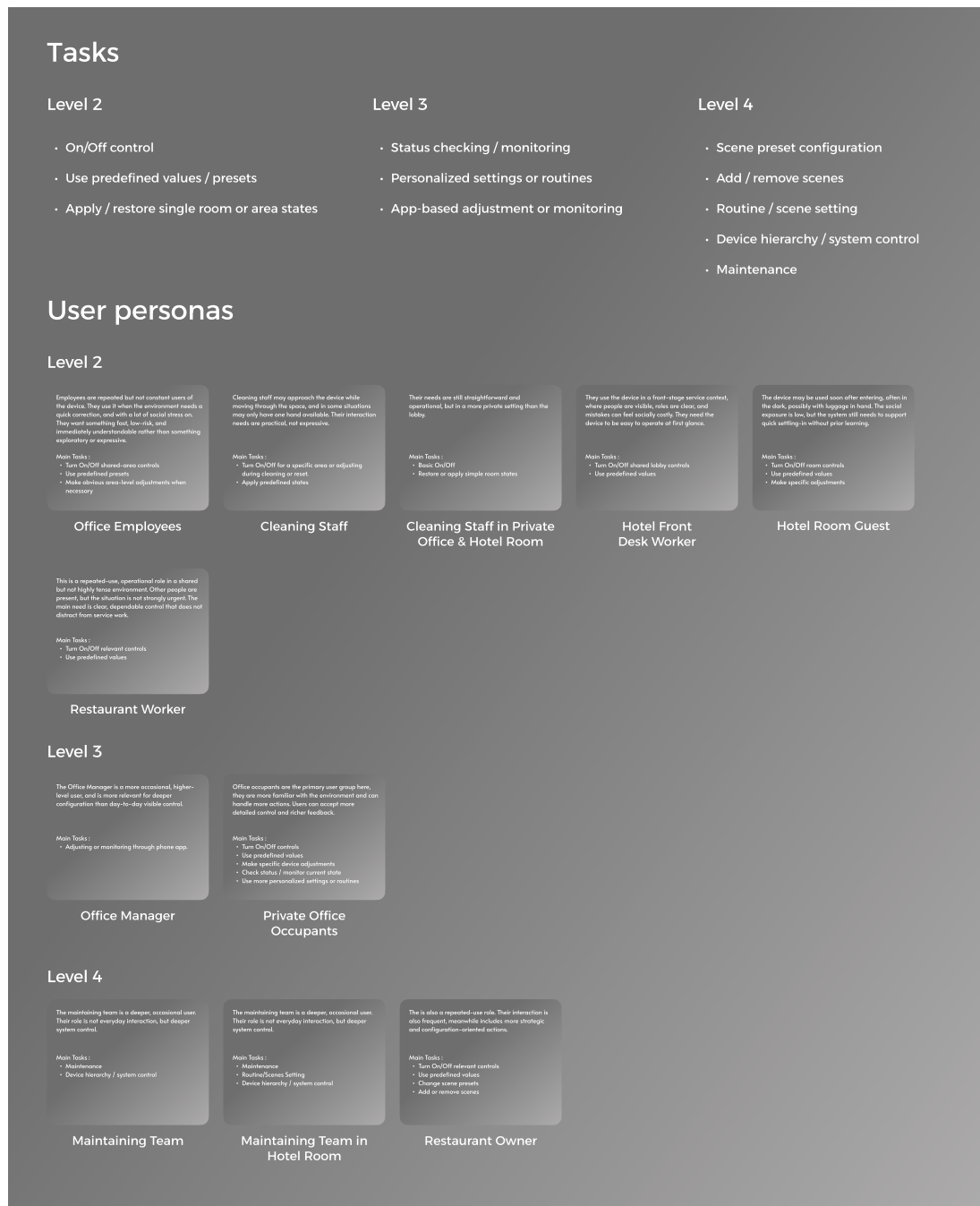
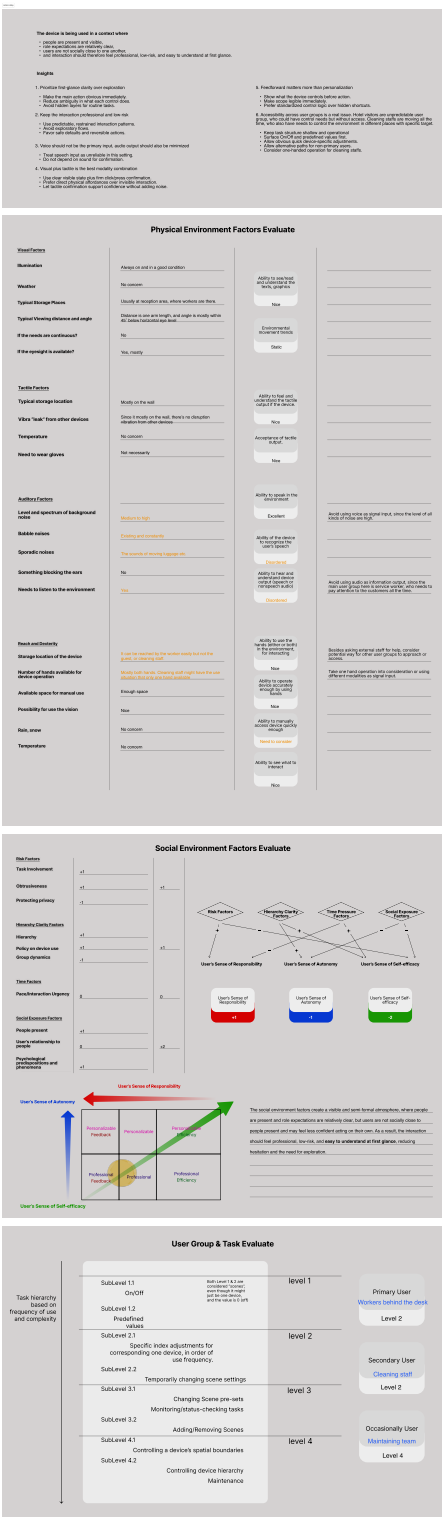


Figure D.1: Tasks summary and user personas



D.5 Personal Office Scenario Analysis

The device is being used in a context where:

- 1. The device is used in a context where:
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- 100. The device is used in a context where:

Physical Environment Factors Evaluate

Factor	Rating	Notes
Visual Factors		
Illumination		
Weather		
Typical Storage Pattern		
Typical Viewing Distance and Angle		
If the needs are considered?		
If the equipment is available?		
Tactile Factors		
Typical Storage Location		
Vibration/Vibration		
Temperature		
Need to wear gloves		
Auditory Factors		
Level and spectrum of background noise		
Sizable noise		
Operative noise		
Screening/Screening the user		
Needs to be in the environment		
Reach and Dexterity		
Storage location of the device		
Number of inputs available for device operation		
Available space for manual use		
Possibility for user the value		
Risk, error		
Temperature		

Social Environment Factors Evaluate

Factor	Rating	Notes
Task Factors		
Task environment		
Observability		
Participatory		
Flexibility/Customization		
Interactivity		
Policy on device use		
Group dynamics		
Task Factors		
Performance/Engagement		
Social/Network Factors		
People present		
User's relationship to device		
Psychological performance and phenomena		

User Group & Task Evaluate

Task Hierarchy	SubLevel	Task Description	Level	User Group	
Task Hierarchy based on frequency of use and complexity	SubLevel 1.1	On/Off	level 1	Primary User Office Occupants Level 3	
	SubLevel 1.2	Power/Off			
	SubLevel 2.1	Power/Off	level 2	Secondary User Cleaning staff Level 2	
	SubLevel 2.2	Temporarily changing scene settings			
	SubLevel 3.1	Changing Scene pre-sets	level 3	Occasionally User Maintenance team Level 4	
	SubLevel 3.2	Monitoring/status-checking tasks			
	SubLevel 4.1	Adding/Removing Scenes			
	SubLevel 4.2	Controlling a device's spatial boundaries			
			Controlling device hierarchy		
			Maintenance		

Figure D.5: Personal office scenario analysis

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