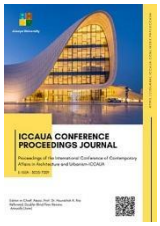

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Innovation in Architectural Harware: Design of Flush-Integrated Linear Motion Door Handle for Smart Doors

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Abstract

This study addresses the integration of aesthetics and functionality in modern architectural hardware by evaluating a flush-integrated door handle design that approaches the user via linear motion. The methodology focuses on a system that remains embedded in the door body when inactive, integrated with smart locking systems and motion sensors. A key aspect is maintaining surface integrity through a minimalist design language compared to traditional handles. Key findings indicate that the use of aluminum ensures high structural durability and sustainability while the sensor support prevents hand entrapment, enhancing user safety. In conclusion, this project combines mechanical innovation with user experience, offering a new perspective for contemporary architectural product designs by prioritizing aesthetics and functionality.

Keywords: Smart Door Systems; Linear Motion; Flush Design; Architectural Hardware; Aluminum Design.

Innovation in Architectural Hardware Systems: Design of a Flush-Integrated Linear Motion Handle for Smart Doors

Abstract:
The aim of this study is to evaluate a flush-integrated door handle design that combines aesthetics and functionality in modern architectural hardware systems and approaches the user through linear motion. As a methodology, the integration of a system that remains concealed within the door body when not in use with smart lock technologies and motion sensors was investigated. A significant aspect of the study is its ability to maintain surface continuity and present a minimalist design language without disrupting the overall appearance of the door, unlike conventional door handles. The main findings indicate that the use of aluminum material provides high structural durability and sustainability, while sensor-assisted operation enhances user safety by preventing the risk of hand entrapment. By combining mechanical innovation with user experience, this project offers an innovative perspective for contemporary architectural product design and contributes to the existing literature.
Keywords: Smart Door Systems; Linear Motion; Flush Design; Architectural Hardware; Aluminum Design.

1. Introduction

In modern architecture, door handle designs have undergone significant transformations due to technological advancements. Historically, door handles functioned solely as mechanisms for opening and closing doors; however, they have evolved over time in response to technological developments and changing user expectations. Today, the widespread adoption of contemporary architectural design principles has encouraged minimalist design approaches. Hidden mechanical solutions that provide visual continuity between products and surrounding surfaces have been developed. As a result, contemporary door handle designs emphasizing aesthetics and functionality have begun to replace conventional handle systems.

The protruding and sharp-edged forms commonly found in traditional door handles may present risks not only from an aesthetic perspective but also in terms of user safety. Previous studies have demonstrated that pointed door handles can cause serious physical injuries, particularly among children (Chaudhry et al., 2005). In this context, optimizing perceived effort and accessibility standards during the design process is critical to ensuring that architectural hardware remains both safe and user-friendly (Paschoarelli et al., 2012).

Exterior doors are generally perceived as large, monolithic architectural elements. The visual continuity of these surfaces is often interrupted by conventional door handles. Linear door handles, whether positioned vertically or horizontally, create visual divisions on the door surface. For this reason, the exterior door handle proposed in this study was designed as a recessed system integrated into the door surface. The contemporary understanding that door handles are important components contributing to architectural coherence has guided this design approach. In a study conducted by Sung Ryeol Shin and Sang Koo, flush-type door handle systems were reported to provide aesthetic continuity within modern design concepts. Accordingly, the door handle developed in this study was designed to remain flush with the door surface.

The proposed design creates a holistic appearance that is compatible with contemporary architectural aesthetics. During use, the handle is activated and moves linearly toward the user, allowing convenient access and operation. Once usage is completed, the handle retracts through a reverse linear motion and returns to its flush position within the door surface. Through this mechanism, the design is intended for smart door applications, including villa entrance doors, hotel projects, and office entrance systems, where it can complement contemporary architecture through a minimalist design language. The proposed system offers an innovative solution by combining aesthetic integrity with functional usability.

Within the scope of this study, the historical development of door handles, ergonomic considerations, and user experience factors were examined. The design process was conducted through the use of mind mapping and morphological analysis methods. Material selection, mechanical integration methods, and emerging technologies were evaluated in order to develop the proposed manufacturing approach. Through the design of a flush-integrated linear motion door handle, the study aims to introduce an innovative design concept that combines technology, aesthetics, and user experience within contemporary architecture.

2. Materials and Methods

2.1 Methodology and Design of Door Handles

This study aims to introduce innovation to door handle design. The proposed approach involves a door handle that remains flush with the door surface when not in use and moves linearly toward the user when activated. By being recessed into the door structure, the designed handle provides a modern appearance while maintaining surface continuity. The evaluations conducted throughout the study contributed to the development of the main framework of the design.

Within the scope of this research, a literature review on door handles was first conducted. Previous studies examining the impact of door handles on safety, compatibility with hand ergonomics, relationships with smart door and architectural systems, manufacturing processes and techniques, and the evolution of door handle design perceptions were evaluated. Stephen Pheasant stated that the primary function of handles is to facilitate the transfer of force generated by the user's musculoskeletal system to the tool or object being operated in accordance with the intended task (Stephen Pheasant, 2006). Following the COVID-19 pandemic, significant changes emerged in door handle design approaches. Contactless operation and technology-integrated door handle systems became increasingly prominent. Hidden mechanical solutions employed in flush-integrated handle systems, commonly used in the automotive, smart device, and home appliance industries, were therefore examined.

Subsequently, the design process was initiated. First, a mind map was developed, followed by a morphological analysis based on the outcomes of the mind mapping process. Within the door handle concept, which is dominated by a user-centered design approach, concepts such as ergonomics, design language, manufacturing process, safety, marketing strategy, user experience (UX), material selection, and durability emerged as key considerations.

Through morphological analysis, parameters including material, form, safety, user experience, activation methods, and mechanism alternatives were evaluated. Multiple concept designs were generated through different combinations of these parameters. The resulting concepts were assessed in terms of ergonomics, user experience, and feasibility. These evaluations played a significant role in shaping the final design.

Following the determination of the design concept, studies focusing on mechanical connection details were conducted. The compatibility of this new technology with smart door systems was examined. When activated by the user, the door handle moves linearly outward from its recessed position toward the user. Once the operation is completed, the handle returns to its flush position within the door surface through a reverse linear motion. To enable this linear movement, rail systems, linear mechanisms, and motor-assisted solutions were investigated and evaluated.

As a result, the final design was established based on the findings obtained throughout the study. The final concept was evaluated using three-dimensional modeling software. The movement mechanism, ergonomics, and manufacturability of the design were verified through simulation studies. The evaluated design stands out in terms of manufacturability, material performance, and user experience. This design approach is intended to introduce a new perspective to the industry by combining aesthetics, ergonomics, and technology.

2.1. History Of Door Handles

Doors are systems composed of door opening elements such as frames, casings, and thresholds, as well as components including hinges, door handles, and locking mechanisms (Edita Riaubiene, 2007). Door handles are architectural hardware elements equipped with mechanisms that enable the opening and closing of doors developed to protect living spaces from external factors. While the earliest examples of door handles consisted of ropes, latches, and simple gripping elements, they have undergone significant technical and aesthetic transformations over time.

The production and design philosophy of door handles has evolved from Ancient Egypt to the present day. Initially, ropes and cords operating on a push-pull principle were used. Following the Roman period, door handles began to develop in terms of craftsmanship and form. Advancements in metalworking technologies enabled the production of more functional and durable door handle systems.

During the Middle Ages, the increasing need for security led to the development of stronger and more durable door handles. Door knockers and door handles evolved both aesthetically and structurally with the widespread adoption of wrought iron manufacturing techniques.

During the seventeenth and eighteenth centuries, modern door handle designs began to emerge. Throughout the Baroque and Renaissance periods, door handles gained aesthetic character under the influence of architecture and art. Door handles manufactured from brass, bronze, and precious metals became symbols of prestige during this era.

The Industrial Revolution introduced mass production into the manufacturing of door handles. Through standardized dimensions and lower production costs, door handles became accessible to broader user groups. The development of locking mechanisms during this period enabled door handles to be integrated with security systems. Naif A. Haddad stated that the evolution of door locking mechanisms represents an important area of research and that lock systems should not be regarded solely as functional requirements for protecting spaces from unauthorized access (Naif A. Haddad, 2016). Ergonomic usability, manufacturability, and functional efficiency became fundamental design criteria during this period.

In the nineteenth century, simplification of form and functionality became dominant characteristics of door handle design. Under the influence of modern architecture, simple geometric forms were preferred and decorative elements were reduced. The introduction of materials such as aluminum and stainless steel significantly improved product durability. Factors including ease of grip, accessibility, and user comfort became increasingly important within design processes.

The influence of the Bauhaus movement accelerated developments in both ergonomics and design throughout the twentieth century. According to Prof. Dr. Şebnem Timur and Dr. Seda Duman (2022), design after the twentieth century shifted its focus from merely shaping objects to transforming human needs and desires into products. In contemporary practice, door handle designs have continued to evolve, particularly following the COVID-19 pandemic. Technological developments associated with changing design perceptions during this period led to the integration of features such as sensor-based access, card-operated systems, and camera-controlled entry mechanisms into door handle systems. Research conducted in a hospital in Italy revealed that approximately 25% of examined door handles contained traces of the virus, indicating that these surfaces represented critical points for disease transmission (Katia Razzini et al., 2020).

Over time, door handles have evolved from simple push-pull mechanisms to systems involving gripping, turning, pressing, and contactless operation, reflecting changing user expectations and experiences. Large-scale door handle systems designed with ergonomic usability, material quality, aesthetic appeal, and contemporary technological features have become particularly prominent in villa entrances and prestigious architectural projects. Through these developments, door handles have evolved from simple functional elements into significant architectural components that influence contemporary design.

2.2. Design Objectives

The design objectives of the exterior door handle are as follows:

- Compatibility with contemporary architecture,
- Enhancing user experience (UX) and introducing an innovative perspective to the industry,
- Ergonomic suitability,
- Introducing innovation to the sector through the door handle mechanism.

Design research contributes to the interpretation and explanation of the concept of function, particularly through studies focusing on technical design and engineering disciplines, thereby providing a valuable source of knowledge for evaluating related research (Nathan Crilly, 2010). One of the primary objectives of this study is to develop a product design that can integrate seamlessly with contemporary architecture. Instead of the protruding block-like appearance commonly associated with conventional door handles, an innovative door handle design that integrates with the door surface was proposed. Through this approach, the door handle becomes an aesthetic component of architectural design.

Another important objective of the design is to enhance user experience and introduce an innovative perspective. The handle is designed to move linearly outward from the surface when activated and, after use, return to its flush position with the door surface by retracting back into the structure.

From an ergonomic perspective, the design aims to ensure user safety while enabling door opening and closing operations with minimum effort through push and pull actions. Grip characteristics, usage angles, and user movement range were developed in accordance with human hand anatomy. Ergonomic evaluations were conducted by considering users from different age groups and with varying physical characteristics.

The mechanical solutions of the door handle were developed in accordance with current technological infrastructures. Considering the increasing prevalence of smart building systems, the handle was designed to be compatible with motors, sensors, and digital control systems.

Ünlükal İlhan and colleagues stated that a door handle is not merely a functional component that enables doors to be opened and closed, but also an important design element that directly affects user experience. They emphasized that technical, ergonomic, and aesthetic engineering criteria should be evaluated together during the design process in order to achieve user satisfaction (Emel Ünlükal, Rukiye Ertan, Kenan Sert, 2025).

2.2.1. Summary of Design Decisions

2.2.1.1 Mind Map

In parallel with the studies of Dr. Novak, Tony Buzan developed the mind mapping method to support the organization and interpretation of information (Crystal Renfro, 2017). Developed by Tony Buzan during the 1970s, mind maps

represent a central idea and its related concepts through branching, tree-like structures (Chrysovalantis Kefalis, Constantine Skordoulis, Athanasios Drigas, 2025). Through the books and publications he produced on mind mapping, Tony Buzan played a major role in the dissemination and international recognition of this technique (Tze Kiong Tee, Mohamed Nor Azhari Azman, Suriani Mohamed, 2014).

In this study, design decisions were developed through mind mapping and morphological analysis. The mind map technique defined by Buzan (2018) was employed to visualize design ideas hierarchically and establish a conceptual framework. In complex engineering designs, the mind mapping approach facilitates the systematic organization of multidimensional design perspectives (Gupta & Kumar, 2022). Mind maps can be described as an organized brainstorming method (Michelco, 1988). They enable the grouping, regrouping, and comparison of concepts (Ayşegül Şeyihoğlu, Ayça Kartal, 2010). The process of reorganizing concepts and synthesizing them into new clusters often leads to the generation of new ideas (Findlay & Lumsden, 1988).

When applying the mind mapping technique, individuals use not only words but also symbols to record ideas. The combined use of words and symbols activates both hemispheres of the brain (Ayşegül Şeyihoğlu, Ayça Kartal, 2010). Reinforcing ideas through words and symbols stimulates imagination and consequently enhances creativity.

Within the scope of the mind map, the main themes of the study were examined. These included ergonomics, design language, manufacturing process, user experience (UX), marketing strategy, materials and durability, and safety.

According to Shamsuddin and colleagues, the primary objective of ergonomics is to establish working conditions that do not pose risks to human health and life and can be considered tolerable (Khairul Akmal Shamsuddin, Ni Mokhtar, Mmamm Aris, Abdul Ta Razak, 2015). Subtopics within ergonomics were also examined. In general, safety, movement, anthropometry, force, and grip were considered.

Within the manufacturing process category, CNC compatibility, ease of manufacturing and assembly, and compatibility with door thickness requirements due to the flush-mounted design were evaluated.

Within the design language category, emphasis was placed on the recessed design approach, monolithic (flush) appearance, concealed handle functionality, and minimalist design principles.

Within the safety category, the possibility of hand entrapment, installation and mechanical safety, and the implications of a concealed handle system were highlighted.

Under the materials and durability category, factors such as suitability for outdoor use, silent operation of the mechanism, and operational lifespan under frequent usage conditions were considered.

Within the marketing strategy category, user experience emerged as a key factor due to the innovative perspective introduced to door handle design. In addition, product storytelling and target audience identification were considered important aspects.

User experience (UX) occupies a significant position among the design themes. The proposed door handle stands out primarily through its user experience. The opening experience and intuitive operation distinguish it from conventional door handle systems.

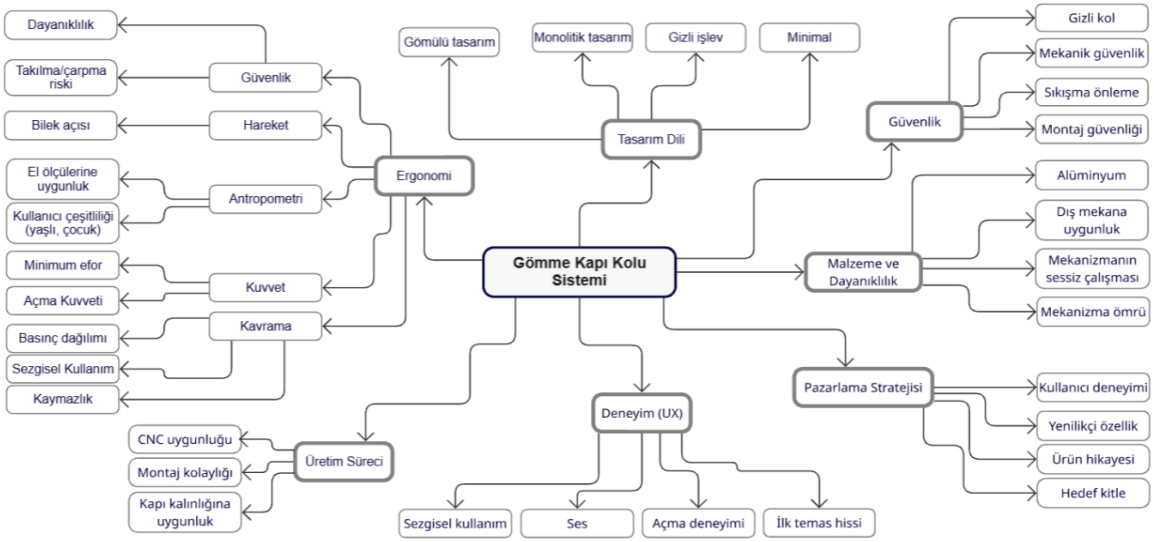

Figure 1. Mind Map.

2.2.1.2. Morphological Analysis

The Morphological Analysis method was introduced by Fritz Zwicky in 1948 during the Halley Lecture delivered at the University of Oxford in the United Kingdom (Tomasz Arciszewski, 2018). According to Fritz Zwicky, who is widely recognized as the founder of morphological analysis research, this method involves the systematic analysis and synthesis of all possible and comprehensive solutions related to a given problem (Zwicky, 1949). Arciszewski defined morphological analysis from an engineering perspective as a method that enables the acquisition of design knowledge, the organization of design problems within an abstract structure, and the systematic development of potential design alternatives (Tomasz Arciszewski, 2017).

Morphological analysis involves transforming complex product problems or design issues into a structured table containing different alternatives, generating combinations among these alternatives, and evaluating the resulting outcomes. In the field of industrial design, morphological analysis provides opportunities to evaluate various factors such

as product form, material selection, manufacturing methods, movement mechanisms (when applicable), ergonomics, and user experience. The concepts obtained from the mind map study were used to establish the table structure of the morphological analysis. A matrix consisting of functions and their alternatives was created. The main categories included material, form, safety, user experience (UX), activation method, and mechanism.
The combinations generated through different pairings played a significant role in the development of the design. Various design alternatives emerged through the application of morphological analysis. This method assists designers in moving beyond existing solutions and developing more original concepts while also facilitating the comparison of alternative designs and the identification of the most suitable solution. The use of morphological analysis in this study contributed to the systematic progression of the design process and supported the development of innovative design proposals.

FONKSİYON	ALTERNATİF 1	ALTERNATİF 2	ALTERNATİF 3	ALTERNATİF 4	ALTERNATİF 5
Malzeme	Paslanmaz Çelik	Alüminyum	Pirinç	Cam + metal	
Form / Yüzey	Hafif çıkıntılı	Hemyüz	Çerçeveli	Gizli yüzey	
Güvenlik	Elektronik kilit	Gizli erişim	Mekanik kilit	Hibrit sistem	
Kullanıcı Deneyimi	Sessiz çalışma	Sezgisel kullanım	Led yönlendirme		
Tetikleme	Dokunmatik basma	Mekanik basma	Hareket sensörü	Yüz tanıma	Parmak izi
Mekanizma	Motorlu	Tam mekanik	Yaylı sistem	Manyetik sistem	Hibrit sistem (motor+yay)

Figure 2. Morphological Analysis.

2.2.2. Linear Motion of The Door Handle

In this study, the door handle system was designed to remain flush with the door surface when not in use and to become active when the door is to be opened, moving linearly toward the user and extending outward from its recessed position. Concealable door handles with rotational and linear motion mechanisms are generally positioned flush with the door body in their initial inactive state and do not protrude from the surface (Jesse Baker and John Miller, 2023).
Accordingly, existing linear motion mechanisms were examined. In recent years, retractable door handle systems utilizing linear motion, particularly in premium-segment and electric vehicles, have attracted attention due to their aerodynamic performance, aesthetic qualities, and ergonomic advantages.
According to Miller, retractable door handle systems used in vehicles remain aligned with the primary surface when inactive and move toward the user when activated under specific conditions. These activation conditions include the approach of a key, the detection of the user's hand through sensors, or a light touch applied to the handle. Once activated, an actuator initiates the mechanism, allowing the handle to extend outward through controlled linear motion. After use, the handle retracts through reverse linear movement and reintegrates with the surface in a flush position. In such systems, precise positioning and operation of the handle are essential to ensure safety and prevent collisions with surrounding objects (John Miller, 2023).
The adaptation of these systems to smart door applications compatible with contemporary architecture can introduce a new design approach and add prestige to villa entrance doors. The system can be activated from both the interior and exterior sides of the door. When not in use, the handle returns through reverse linear motion and becomes flush with the door surface once again. In this way, a minimalist aesthetic appearance compatible with contemporary architecture is achieved.
The operation of the door handle begins when the user activates the system. The system is designed to be compatible with touch sensors, card access systems, fingerprint readers, and smart home technologies. When activated through one of these methods, the motor mechanism within the system initiates controlled linear movement of the handle along its designated axis.
When the handle extends from its recessed position, an ergonomic form suitable for user grip is presented. The handle geometry was developed based on research findings and ergonomic evaluations. To prevent hand entrapment, a motion sensor is integrated into the inner surface of the handle. After the user completes the operation, the system enters a standby mode. Working in conjunction with the motion sensor, the system monitors user activity and, when no movement is detected after a specified period, performs a reverse linear motion to return the handle to its flush position within the door surface. Zhai, Bai, Shi, Tang, and Shi (2025) investigated sensor-based systems, emphasizing sensor placement and integration strategies capable of meeting user requirements. Their findings were examined in the development process, highlighting the importance of integrated sensors in addressing user needs and improving user experience.
In this study, the linear motion mechanism operates through a rail-guided system. Controlled and silent operation was identified as a primary design objective. Therefore, particular attention was given to minimizing friction between system components. Since frequent usage of the product is anticipated, ensuring system durability and maintaining reliable long-term operation without mechanical failure were considered essential design requirements.
The study conducted by Ben Kasemsadeh and Luke LaPointe, which investigated metal surfaces functioning as buttons and activating motion detection systems during pressing actions, was also examined. In such systems, sensors interact with the force applied by the user (Ben Kasemsadeh, Luke LaPointe, 2016).
A motion sensor was incorporated into the door handle system as a safety measure. For access from the exterior, only authorized users are permitted to activate the system. However, individuals exiting from the interior are considered authorized users by default, as they are leaving a secure area and must be able to operate the door. Restricting system activation to authorized users enhances overall security. The motor operates using electrical power. In the event of a

power failure and the absence of generator backup, the system can be operated manually. When the door is opened through the manual locking mechanism, the handle system is also activated.
Through the linear motion mechanism employed in this study, the door handle is positioned flush with the door surface when inactive. By reinterpreting the conventional concept of door operation, the proposed design differentiates itself from traditional door handle systems. By combining technology with user experience, the system preserves contemporary architectural surface continuity while offering an innovative solution for the industry.

3. Results

As a result of the research, design, conceptual development process, and user-oriented evaluations conducted within the scope of this study, various findings were obtained regarding the flush-integrated door handle system. These findings were evaluated under the categories of user experience (UX), mechanical structure, contemporary technology integration, and ergonomics.
The research phase of the study included an extensive literature review. The findings indicated that user needs and contemporary architectural approaches increasingly favor minimal and holistic design solutions. It was observed that conventional protruding door handles fail to maintain surface continuity. Furthermore, design solutions that preserve a unified appearance in modern architecture are perceived as more contemporary and prestigious.
The mind map analysis revealed that users expect more than functional performance from a door handle. Users also expect compatibility with hand ergonomics, integration with smart home systems, harmony with architectural façades, and a premium user experience. From a user experience (UX) perspective, the fact that the handle does not remain permanently visible but only extends toward the user when needed was identified as a distinctive feature. This intuitive mode of operation is expected to introduce a new perspective to the industry.
When the design alternatives generated through morphological analysis were compared, the linear motion mechanism was identified as the most suitable solution for a flush-integrated door handle system. Compared to rotating or folding mechanisms, the linear motion system was found to provide a more controlled operation while preserving surface continuity.
The ergonomic evaluation demonstrated that the extension of the handle toward the user after activation provides ease of grip and accessibility. Human hand anatomy was considered to ensure that the handle could be operated with minimum physical effort.
The door handle developed within the scope of this study was found to have strong potential for integration with smart home systems through compatibility with motion sensors, automation technologies, and digital access systems. Due to its suitability for contactless operation and intelligent building infrastructures, the proposed system is expected to gain wider adoption in future architectural applications.
Based on the findings obtained, the flush-integrated door handle was evaluated as an innovative solution that combines aesthetics and contemporary technology while addressing the requirements of modern architectural applications.

4. Discussion

The flush-integrated door handle developed in this study represents an innovative approach that reinterprets conventional door handle systems while addressing the requirements of contemporary architecture and evolving user expectations. The findings indicate that door handles should no longer be considered solely as functional products but also as important design elements influenced by technology integration, contemporary aesthetic values, and user experience (UX). The minimalist design philosophy that has gained prominence in contemporary architecture contributes to the perception of flush-integrated door handle systems as premium and modern products. The advantages offered by flush-type handles, particularly those employed in the automotive industry to enhance aesthetics and functionality, also demonstrate significant potential for application within intelligent architectural hardware systems (Shin & Koo, 2025).
The linear motion mechanism utilized in this study was found to offer advantages over fixed or rotational door handle systems in terms of preserving architectural continuity. The fact that the handle is visible only when activated supports the visual integrity of the architectural environment. However, the linear motion mechanism also increases the technical complexity of the product. Compared with conventional systems, this approach requires more detailed engineering solutions concerning manufacturing costs, mechanical durability, and maintenance requirements.
From an ergonomic perspective, the extension of the handle from its recessed position through linear motion improves usability by providing easier access for the user. However, since flush-integrated door handles differ from conventional handle systems familiar to most users, an adaptation period may be required. Because users are accustomed to visible and permanently accessible door handles, their perception and activation of the product during initial use may vary. Therefore, the effective design of motion sensors, user interfaces, and feedback systems is essential for ensuring intuitive operation.
The compatibility of the proposed door handle with smart home systems significantly enhances its future application potential. However, the integration of electronic components introduces new areas of consideration, including energy consumption, potential technical failures, and system security.
The flush-integrated door handle offers significant technological and aesthetic advantages. Nevertheless, since users may not be familiar with this type of system, different usage scenarios should be tested and evaluated. The durability of the linear motion mechanism, its long-term operational performance, and maintenance requirements represent important research areas for future studies.
In conclusion, the recessed door handle system presents an innovative product approach that combines contemporary technology with the minimalist design philosophy that has become increasingly important in modern architecture. This study demonstrates that door handles are evolving beyond purely functional components and are becoming technology-enhanced design elements that influence both user experience (UX) and spatial perception.

Figure 3. Perspective View of the Door Handle in the Activated Position.

Figure 4. Front View of the Door and Door Handle in the Flush Position .

5. Conclusions

Within the scope of this study, a door handle design developed in accordance with contemporary architectural principles and aimed at meeting user experience (UX) expectations was examined, resulting in the proposal of an innovative product concept through the integration of current technologies. Unlike conventional door handles, the proposed system remains flush with the door surface when inactive and is activated only when required by the user. Upon activation, the handle moves linearly toward the user, providing both visual and functional integration with contemporary architectural environments.

At the beginning of the study, a comprehensive literature review was conducted. Previous studies examining ergonomic suitability, safety considerations, manufacturing processes, and production techniques were evaluated, and the historical development of door handles was investigated. The findings indicated that contemporary users increasingly demand solutions that combine technological integration with architectural continuity. In response to these expectations, the proposed flush-integrated door handle design offers an approach that enhances user experience while supporting a minimalist surface concept.

The linear motion mechanism enables the handle to extend toward the user in a controlled manner during operation and remain recessed and flush with the surface when not in use. This approach introduces an innovative design concept. When users exit from the interior space, the system automatically becomes active, allowing them to operate the exterior linear-motion handle. Users approaching from the exterior can activate the handle either by applying pressure to the designated surface area or through the smart home system integrated with the door handle. Designed to be compatible

with smart home technologies and automation infrastructures, the proposed system is capable of adapting to future living environments.
Ergonomic criteria were carefully considered throughout the form development process of the door handle. User experience, hand anatomy, and grip behavior were analyzed to ensure that the handle could be operated with minimum physical effort.
In conclusion, this study demonstrates that a flush-integrated door handle design can offer more than a simple door-opening mechanism. By improving user experience, integrating contemporary technologies, and maintaining compatibility with modern architectural principles, the proposed system presents an innovative design approach. The completed door handle design has the potential to be implemented in villa entrance projects, hotel facilities, and office buildings. Furthermore, this study provides a foundation for future developments involving hardware systems integrated into movable architectural surfaces.

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Conflicts of Interest
The authors report no conflicts of interest.

Data Availability Statement
All data generated or analyzed during this study are fully integrated within this published manuscript. Additional requests for specific technical layout details can be directed to the corresponding author.

Institutional Review Board Statement
Not applicable. This study did not involve experimental interventions on human or animal subjects, focusing entirely on technical hardware design and application methodologies.

Credit Author Statement
Nisa Nur Çam: Conceptualization; Data curation; Methodology; Investigation; Resources; Software; Visualization; Writing – original draft. **Ahmet İnci** Supervision; Writing – review & editing; Verification. All authors have read and approved the final manuscript.

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