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A Study on the Application of Industry 5.0 Technologies in Residential Welfare

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Abstract

Purpose: This study aims to analyze the application of Industry 5.0 technologies to improve residential welfare, focusing on vulnerable groups such as the elderly and one-person households. **Research design, data, and methodology:** Through a literature review and SWOT analysis, it examines both the strengths and challenges of these technologies, which include AI, IoT, energy management solutions, and personalized systems. **Results:** The application of Industry 5.0 technologies in residential welfare offers opportunities for enhanced personalization, energy efficiency, and security, especially for vulnerable groups like the elderly and one-person households. However, challenges such as high costs, data privacy, infrastructure limitations, and technological inequality must be addressed to ensure equitable access and widespread adoption. **Conclusions:** The research identifies key areas for improvement, including data privacy, infrastructure limitations, and the need for equitable access to advanced housing solutions. By addressing these areas, the adoption of Industry 5.0 technologies can help create a more resilient, inclusive, and efficient residential welfare system for future generations.

Keywords: Industry 5.0, Residential welfare, Personalized systems, Data privacy, SWOT analysis

JEL Classification Code: R14, R21, R31, R38, R58

1. Introduction

The transition from Technology 4.0 to Technology 5.0 marks a critical juncture in modern technological and societal advancement, characterized by the shift from automation and digitization toward more human-centric solutions. Industry 5.0 focuses on harmonizing human creativity and intelligence with the capabilities of advanced technologies such as artificial intelligence (AI), robotics, the Internet of Things (IoT), and data analytics. This paradigm shift is not only transforming industries but also extending its influence to various social sectors, including residential welfare.

In recent years, many societies have experienced significant demographic changes, particularly the rise of one-person households and the rapid aging of populations. These trends are especially prevalent in urban areas, where housing systems are under increasing pressure to meet the evolving needs of these groups. One-person households, comprising both younger individuals and elderly persons,

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face unique challenges, including affordability constraints, social isolation, and limited access to essential services. Similarly, aging populations require housing solutions that are adaptable to their specific needs, such as senior-friendly design, healthcare integration, and improved accessibility.

These demographic shifts present complex challenges for residential welfare systems, which must evolve to provide adequate, equitable, and sustainable solutions. Traditional housing policies and welfare systems are often ill-equipped to address these demands, necessitating innovative approaches. Industry 5.0 technologies offer a promising pathway for reshaping residential welfare through personalized, data-driven solutions that can enhance the quality of life for vulnerable groups. By leveraging AI, IoT, and robotics, housing systems can be designed to provide responsive, tailored services that address the unique needs of one-person households and the elderly, thereby improving their well-being and social inclusion.

This study explores the potential of Industry 5.0 technologies to address the pressing issues in residential welfare, particularly in the context of these demographic trends. The integration of these technologies into housing systems represents an opportunity to not only improve the living conditions of marginalized populations but also to create a more resilient, efficient, and equitable housing framework that can adapt to future societal changes. The primary objective of this study is to identify and propose strategies for the application of Industry 5.0 technologies in residential welfare, while simultaneously outlining the challenges associated with their implementation. Specifically, the study aims to explore how advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), robotics, and data analytics can be integrated into residential welfare systems to enhance the quality of life for residents, particularly focusing on vulnerable groups such as one-person households and the aging population.

In addition to identifying potential solutions, this study will thoroughly examine the practical, technical, and ethical challenges associated with the deployment of these technologies. This includes assessing the policy adjustments, infrastructure development, and stakeholder cooperation required for effective implementation, as well as addressing concerns related to privacy, equity, and accessibility to ensure that these technological advancements benefit all sectors of society, especially those at risk of exclusion.

The purpose of this study is illustrated in Figure 1. The study focuses on the application of Industry 5.0 technologies to enhance residential welfare, ensuring that technological advancements are aligned with human needs. Through this, the research seeks to propose strategies that will improve the overall well-being and quality of life for individuals, particularly in socially and economically vulnerable communities.

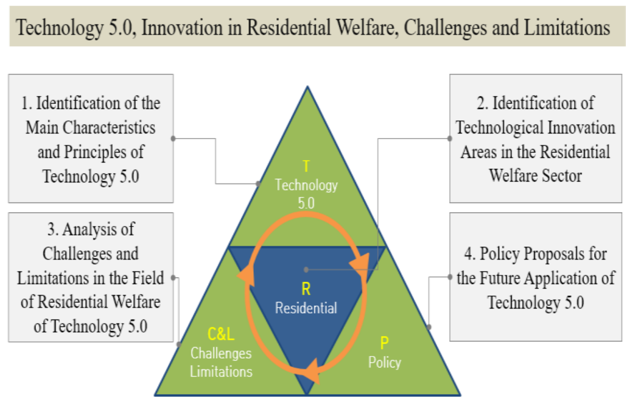

Figure 1: The purpose of study

2. Literature Review

2.1. Industry 5.0 and Sustainable Development

Industry 5.0 is increasingly being recognized for its potential to drive sustainable development through disruptive technologies and advanced integration with social and environmental frameworks. According to Kasinathan et al. (2022), the incorporation of Industry 5.0 technologies has the potential to significantly contribute to the realization of the Sustainable Development Goals (SDGs), by mapping key transformative scenarios that involve both Industry 5.0 and Society 5.0. This view is supported by Baig and Yadegaridehkordi (2024), who provide a detailed analysis of Industry 5.0 applications for sustainability and future research directions, indicating that these technologies can address environmental challenges while also enhancing industrial efficiency.

Industry 5.0's ability to transform manufacturing into more sustainable and human-centric operations is another key area of focus. Narkhede et al. (2023) emphasize that Industry 5.0 extends the principles of Industry 4.0 by integrating social and industrial challenges, particularly within sustainable manufacturing. Furthermore, the integration of blockchain technology into Industry 5.0 offers additional opportunities for creating sustainable, resilient industrial applications (Fraga-Lamas et al., 2024). In the context of smart cities, Mishra et al. (2022) explore how Industry 5.0 and Society 5.0 together contribute to building sustainable urban environments through digital innovations.

2.2. Core Technologies & Trends in Industry 5.0

Core technologies driving Industry 5.0 are also essential to its success. Ghobakhloo et al. (2023) identify the key technologies, components, and values of Industry 5.0, emphasizing how the integration of advanced robotics, artificial intelligence (AI), and the Internet of Things (IoT) facilitates the development of more human-centric industrial systems. Tallat et al. (2023) similarly highlight the enabling technologies and trends that are shaping the transition from Industry 4.0 to Industry 5.0. These technologies have significant applications in sectors such as healthcare, where Jeyaraman et al. (2022) demonstrate how Industry 5.0 is driving innovation in orthopedics through digitalization and human-machine collaboration.

2.3. Human-Centric Applications of Industry 5.0

Human-centric applications are central to Industry 5.0’s ethos. Gladysz et al. (2023) point out the importance of Operator 5.0 in enabling seamless collaboration between humans and machines, while Tyagi et al. (2024) discuss the transformative impact of Industry 5.0 on human resources, particularly in terms of automation and workforce management. Taj and Zaman (2022) highlight the critical role of explainable artificial intelligence (AI) in ensuring that human-centric technologies remain transparent and understandable, further advancing Industry 5.0's goals.

2.4. Integration of Industry 5.0 and Society 5.0

Finally, the integration of Industry 5.0 with Society 5.0 offers new opportunities for social innovation. George and George (2024) discuss how emerging technologies within Society 5.0, such as AI, are reshaping industries and creating human-centered solutions for complex societal challenges. Rehman and Umar (2024) further explore the potential of Industry 5.0 technologies in advancing environmental, social, and governance (ESG) objectives in corporate settings, emphasizing the role these technologies play in enhancing corporate sustainability.

Despite the extensive research on Industry 5.0 technologies and their applications across various sectors, there remains a significant gap in the exploration of how these technologies can be applied to residential welfare. Existing studies largely focus on the industrial, environmental, and social innovations driven by Industry 5.0, but the integration of human-centered technologies specifically into housing and welfare systems has not been adequately addressed. This presents a critical gap, as the application of human-centric technologies in residential welfare has the potential to transform housing systems, particularly for vulnerable populations such as the elderly and those in one-person households.

The focus on technology for humanity, which is central to Industry 5.0, aligns perfectly with the objectives of housing welfare improving the quality of life, accessibility, and inclusivity in living environments. Therefore, the exploration of how advanced technologies such as AI, IoT, and robotics can be effectively integrated into housing welfare systems to enhance personalized services, accessibility, and sustainability is not only timely but essential. This study seeks to address this gap by providing innovative solutions and strategies for applying Industry 5.0 technologies in residential welfare, emphasizing the need for a human-centered approach in both design and implementation.

This research distinguishes itself by focusing on the intersection of Industry 5.0 technologies and housing welfare, an area that has been largely underexplored. The study aims to contribute to the development of more responsive, inclusive, and sustainable housing systems by leveraging the potential of advanced technologies, addressing the unique needs of growing one-person households and the aging population.

3. Analysis Framework

3.1. Analysis Objective

The primary objective of this study is to analyze the changes and tasks that are influenced by the technological advancements brought about by Technology 5.0, specifically in the real estate sector with a focus on residential welfare. The research aims to understand how Technology 5.0 can be applied to enhance residential systems, improve living standards, and address socio-economic challenges within this sector.

3.2. Analysis Procedure

The study will follow a structured three-step analysis procedure:

Step 1: Investigate and analyze the technology trends and characteristics of Technology 5.0. This involves understanding the key technologies driving Technology 5.0 and identifying their implications for various sectors, particularly real estate and residential welfare.

Step 2: Analyze the application of Technology 5.0 within the real estate industry. The focus will be on how these technologies can be leveraged to create smarter, more efficient residential systems, addressing issues such as affordability, sustainability, and accessibility in residential welfare.

Step 3: Identify the applicable fields for each technology and derive the specific tasks that need to be addressed during the development process. This will include formulating strategies for integrating Technology 5.0 technologies into residential welfare and determining the necessary infrastructure and policy adjustments required for their successful implementation.

By addressing both technological and human-centric challenges, it seeks to create more efficient, sustainable, and personalized living environments.

3.3. Analysis Methods

The analysis methods employed in this study include a comprehensive literature review and a detailed SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis. The literature review helps to provide a solid foundation by examining previous research and developments related to Technology 5.0 and its potential applications in various sectors, particularly in residential welfare. This method allows for the identification of existing gaps in knowledge and helps to highlight how emerging technologies can be leveraged to improve housing and living conditions.

In addition, the SWOT analysis methodically assesses both the internal and external factors influencing the adoption of Technology 5.0 in residential welfare. It evaluates the strengths and advantages, such as enhanced operational efficiency, improved sustainability, and the ability to personalize services for individuals based on their specific needs. Concurrently, it identifies potential weaknesses, including implementation challenges, existing technological barriers, and the financial constraints that may arise in deploying advanced technologies on a larger scale.

The analysis examines the opportunities brought by innovative technologies that have the potential to enhance the adaptability and efficiency of residential welfare systems. Simultaneously, it addresses significant challenges such as data privacy issues, unequal access to technology across socioeconomic groups, and the risks of job displacement due to increased automation in residential services.

By incorporating these factors, the study seeks to develop strategic frameworks and practical approaches for integrating Technology 5.0 into residential welfare. The goal is to not only ensure that the adoption of these advanced technologies is feasible but also to maximize their social and economic benefits, particularly for vulnerable demographics such as single-person households and the aging population.

Ultimately, this dual-method approach provides a roadmap for addressing both technological advancements and human-centric challenges, leading to the development of more efficient, sustainable, and inclusive residential environments.

4. Analysis Results

4.1. Technology 5.0

4.1.1. Technology 5.0 Features

In the era of Technology 5.0, there will be a significant emphasis on fostering a deep coexistence between humans and machines. This new phase of technological development is expected to revolutionize how humans and machines interact, particularly in public and professional settings where close-proximity collaborative tasks will become increasingly sophisticated.

Humans will be required to engage more thoughtfully and attentively with machines, taking into account their behaviors, outputs, and the advanced capabilities they bring to various tasks. Simultaneously, machines, enhanced with artificial intelligence and sensors, will evolve to recognize and respond to human emotions, preferences, and needs in real time, allowing for a more seamless and intuitive interaction. This dynamic, interactive relationship will not only improve efficiency and productivity but also drive mutual growth for both humans and machines. Through continuous feedback and adaptation, humans will benefit from the precision and analytical power of machines, while machines will learn and improve from their interactions with human operators, becoming more adept at addressing complex, human-centered tasks.

Ultimately, Technology 5.0 aims to create an environment where technology works in close harmony with human creativity and decision-making, pushing the boundaries of what can be achieved through human-machine collaboration.

The comparison between Technology 5.0 and its predecessors outlined in Table 1, demonstrates the evolution from basic mechanization to more advanced, human-centric integration, showcasing how each technological stage progressively built upon the innovations of its predecessor, advancing from the rudimentary automation of tasks to the sophisticated incorporation of artificial intelligence, machine learning, and real-time human interaction. Technology 5.0 represents the pinnacle of this technological trajectory, with its core emphasis on achieving seamless synergy between machines and human needs, thereby promoting the development of systems that are increasingly intuitive, personalized, and responsive, and capable of adapting in real-time to enhance user experience and operational efficiency.

Table 1: Technology 5.0 Features

5C	Technology 1.0, 2.0, 3.0, 4.0	Technology 5.0
Co-existence	Machines and humans work in separate domains	Humans and machines collaborate and coexist interactively
Connectivity	Limited or no real-time connectivity	Full real-time connectivity across systems and platforms
Communication	Basic machine-to-machine communication	Advanced human-to-machine and machine-to-machine communication
Customization	Standardized and mass-produced system	Highly personalized and customizable to individual needs
Cognition	Machines operate based on pre-defined instructions	Machines equipped with AI that understand and respond to human emotions, needs, and preferences

Sources: Lu et al. (2022), Author reconstruction

4.1.2. Technology 5.0 Classification

The classification of technologies relevant to Technology 5.0 for enhancing residential welfare systems encompasses a wide range of advanced and emerging technological categories, each designed to significantly improve the quality of life within residential environments. These technologies are diverse, ranging from innovations that enhance human-machine interactions to those that improve energy efficiency and sustainability. By integrating cutting-edge solutions such as artificial intelligence, smart materials, and virtual simulation, Technology 5.0 aims to create more responsive, intelligent, and efficient residential systems that cater to the evolving needs of modern society. This approach fosters not only technological advancement but also promotes the development of residential environments that are more adaptable, sustainable, and aligned with human well-being.

First, Individualized Human-Machine Interaction Efficiency includes cutting-edge technologies such as Collaborative Robots (COBOTs), SCARA (Selective Compliance Articulated Robot Arm), and Face API. These technologies are designed to improve the efficiency and personalization of interactions between humans and machines, enabling more responsive and customized services in residential environments. For example, COBOTs can work alongside humans to assist with tasks, while Face API allows machines to recognize and respond to human emotions and identities in real-time.

The second category, Bio-inspired Technologies and Smart Materials, features Smart Cell technology, which is inspired by natural biological processes. These materials and systems are designed to create more adaptable, sustainable, and efficient solutions for residential environments, promoting energy conservation and responsiveness to environmental changes.

In the Digital Twins and Simulation category, technologies like Digital Twins (DT), Man-Machine

Integration, and Virtual Reality Modeling (VRM) are highlighted. These innovations allow the creation of virtual replicas of physical systems, enabling real-time monitoring, simulation, and optimization of residential environments. This capability can assist in the efficient design, construction, and ongoing management of residential spaces by simulating various scenarios.

The Data Transmission, Storage, and Analysis Technologies category includes essential technologies such as cloud computing and the Internet of Things (IoT), particularly in industrial contexts, with the support of upcoming advancements like 6G and beyond.

These technologies are crucial for handling the vast amounts of data generated by modern residential systems, ensuring faster, more reliable connectivity and improved data management for smarter homes.

Next, Artificial Intelligence (AI) 5.0 represents the next generation of AI, capable of predicting, learning, and adapting to various environments. In the residential welfare context, AI 5.0 is expected to optimize a wide range of systems, such as energy management, healthcare, and security, making homes more intelligent, efficient, and responsive to the needs of residents.

Lastly, the category of Energy Efficiency, Renewable Energy, and Energy Storage Technology includes innovations like Grid 2030, hydrogen energy systems, and Energy Storage Systems (ESS). These technologies focus on advancing sustainable energy solutions, enhancing energy efficiency, and improving storage capabilities to better manage energy resources in residential environments. These innovations aim to provide more reliable and eco-friendly energy solutions for future smart homes.

This comprehensive classification of technologies underscores the potential of Technology 5.0 to revolutionize residential welfare by integrating advanced solutions that are more intelligent, responsive, and environmentally sustainable.

Table 2: Technology 5.0 Classification

Classification	Applicable Technology
Individualized Human-machine Interaction efficiency	COBOTs, SCARA, Face API
Bio-inspired technologies and smart materials	Smart Cell
Digital twins and simulation	DT (Digital Twins), Man-Machine Integration, VRM (Virtual Reality Modeling)
Data transmission, storage, and analysis technologies	Cloud computing & IoT (Industrial internet of things) 6G and beyond
Artificial Intelligence (AI)	AI 5.0
Energy efficiency, Renewable energy, Energy storage technology	Grid 2030, Hydrogen energy, ESS (Energy Storage System)

4.2. Technology 5.0 & Residential Welfare

4.2.1. Trends and Predictions

Several key trends and predictions emerge from the study of Technology 5.0's impact on residential welfare.

First, the symbiosis of humans and data-driven technology will be a central focus. Technology 5.0 will foster a closer collaboration between humans and intelligent machines, enhancing productivity and overall quality of life in residential environments.

Second, the evolution of Technology 5.0 will have a significant impact on the workforce. Continued advancements in this area will bring about major changes in the roles of workers in the real estate and construction sectors, with increased reliance on technology-driven solutions.

Lastly, there will be a growing need for professional training. As the technological environment evolves, the demand for skill development and training will rise, Data transmission, storage, and analysis technologies are advanced systems for handling vast amounts of data to enhance decision-making in residential management and development.

4.2.2. Technology 5.0 & Residential Welfare

Table 3 comprehensively outlines the application of various technologies and the challenges they pose, offering a clear view of the latest developments in housing welfare technology and the associated issues that need to be addressed.

First, Individualized Human-Machine Interaction Efficiency involves technologies like COBOTs, which are used for residential assistance and smart home systems, while SCARA is employed in assembly manufacturing to automate specific tasks. Face API is utilized for security and personalized services in housing. These technologies are mainly applied to residential assistance, smart home functions, security, and personalized services. However, challenges include safety, user-friendliness, precision, cost, privacy, and accuracy.

Second, Bio-Inspired Technologies and Smart Materials such as Smart Cell technology are used for ventilation, cooling, automatic window control, and heat regulation in homes. This technology contributes to creating energy-efficient residential environments. However, it faces challenges such as cost, market coverage, durability, environmental issues, and energy efficiency. \

Third, Digital Twins and Simulation involve the use of Digital Twins (DT) for building management and residential design, while Man-Machine Integration is applied in smart home interfaces, health, and welfare applications. VRM (Virtual Reality Modeling) is used for virtual model houses and interior design. These technologies benefit building management, design, and virtual environments, but they face challenges such as data supplementation, accuracy, user interface, privacy, realism, and accessibility.

Fourth, Data Transmission, Storage, and Analysis Technologies include Cloud Computing and IIoT (Industrial Internet of Things), which are applied to smart home management, energy management, and security. 6G and Beyond technologies enable high-speed internet for home offices, home education, and automated traffic systems. These technologies improve home management and security but face challenges such as data security, privacy, device compatibility, and communication infrastructure issues.

Table 3: Technology 5.0 in Residential Welfare

Classification	Applicable Technology	Applications	Challenges
	COBOTs	Residential Assistance, Smart Home	Safety, user-friendliness

Individualized Human-machine Interaction efficiency	SCARA	Assembly manufacturing, Automate specific tasks	Precision, cost
	Face API	Security, Personalized service	Privacy, accuracy
Bio-inspired technologies and smart materials	Smart Cell	Ventilation, cooling, Automatic windows, Heat control	Cost, Market coverage, Durability, Environmental Issues Energy efficiency
Digital twins and simulation	DT (Digital Twins)	Building management, Residential design	Data supplementation, Accuracy
	Man-Machine Integration	Smart home interface Health and welfare	User interface Privacy
	VRM (Virtual Reality Modeling)	Virtual model house Interior design	Realism, Accessibility
Data transmission, storage, and analysis technologies	Cloud computing, IoT(Industrial internet of things)	Smart home management Energy management Security	Data security Privacy Device compatibility
	6G and beyond	High-speed internet environment Home Office, Home Edu net Automated traffic system	Establishment of communication infrastructure Electromagnetic wave problem
Artificial Intelligence (AI)	AI 5.0	Personalized Living Environment Health monitoring Energy Efficiency Management Security safety	SData privacy Interface interaction Accessibility of technology
Energy efficiency, Renewable energy, Energy storage technology	Grid 2030	Intelligent power management Renewable energy integration	Infrastructure investment Data security
	Hydrogen energy	Hydrogen fuel cell Hydrogen-based heating system	Storage and Safety Production Delivery infrastructure
	ESS (Energy Storage System)	Peak load management renewable energy storage	Storage capacity and efficiency Base cost issue

Fifth, Artificial Intelligence (AI), particularly AI 5.0, is used to create personalized living environments, health monitoring, energy efficiency management, and security in housing. However, this technology faces challenges such as data privacy, interface interaction, and accessibility.

Lastly, Energy Efficiency, Renewable Energy, and Energy Storage Technology focus on Grid 2030, which enables intelligent power management and renewable energy integration. Hydrogen Energy involves hydrogen fuel cells and hydrogen-based heating systems, while ESS (Energy Storage System) manages peak load and renewable energy storage.

These technologies face challenges such as infrastructure investment, data security, storage, safety, and cost-related issues like base costs and production.

In summary, while these technologies offer promising solutions for modern housing welfare, they each present unique challenges that must be addressed for effective implementation.

4.2.3. SWOT Analysis

The SWOT analysis summarizing the application of technology 5.0 in residential welfare is presented in Table 4.

Here's a SWOT analysis based on the application of various technologies in residential welfare as described.

COBOTs enhance efficiency in residential assistance, especially in elderly care, ensuring safety. However, the high costs and user-friendliness issues, particularly for non-tech-savvy users, pose significant challenges. There is a growing demand for assistive technologies in smart homes, particularly for elderly care, which presents an opportunity for broader adoption. Nevertheless, technological inequality remains a threat, as only high-income households may be able to afford such technologies, limiting market penetration.

SCARA (Selective Compliance Assembly Robot Arm) SCARA automates housing construction, reducing manual labor and boosting productivity. The main challenges lie in the precision limitations, high costs, and scalability, particularly for small-scale projects. Opportunities exist in automation integration within smart home solutions, providing scalable options. However, automation could lead to job losses and resistance from the labor force, posing a potential threat.

Face API enhances home security through personalized access and biometric identification, offering both convenience and safety. However, privacy concerns, especially regarding data storage and the risks of misidentification, present significant weaknesses. The post-pandemic growth in contactless access and secure entry systems in smart homes offers a promising opportunity for this technology. On the other hand, regulatory scrutiny and data privacy laws could limit widespread adoption.

Smart Cell technology boosts home security by providing personalized access and identification. However, privacy concerns related to biometric data and risks of misidentification remain weaknesses. The growing demand for contactless access, particularly in gated communities, presents opportunities for expansion. Nevertheless, regulatory scrutiny and privacy laws could limit the adoption of these technologies.

Digital Twins provide detailed simulations for building management, allowing for better planning, monitoring, and optimization of housing systems. However, implementing DT technology requires a large amount of accurate data, posing challenges for homes lacking digital infrastructure. As more homes adopt digital management, DT could become a standard tool for optimizing and maintaining housing infrastructure. Still, high costs, data accuracy concerns, and slow integration into housing welfare systems pose significant threats.

Man-Machine Integration enhances smart home systems by creating intuitive, responsive homes for occupants. However, privacy concerns and the complexity of user interfaces, especially for non-tech-savvy individuals, pose challenges. There is a growing interest in personalized smart homes, which could drive demand for intuitive interfaces, health monitoring, and accessibility features. However, the increased reliance on real-time data raises concerns about potential cyber threats and data breaches.

VRM allows for virtual housing design and customization, enabling residents to visualize and plan spaces more effectively. However, the high costs of implementing VR technology and the need for advanced hardware limit its accessibility to high-end housing developments. The demand for customizable housing solutions, particularly in the real estate sector, offers significant opportunities for VRM technology. However, VR technology may face challenges related to realism and accessibility, with some users struggling to use virtual platforms effectively.

Cloud computing and IoT improve smart home systems by providing real-time data, seamless connectivity between devices, and more efficient energy management. However, privacy concerns related to data storage and real-time monitoring, along with potential device compatibility issues, may limit widespread adoption. Opportunities arise from the growth of smart cities and energy-efficient homes, which will drive demand for cloud-integrated, IoT-based smart home solutions. However, cybersecurity risks and data breaches pose a significant threat as more devices become interconnected.

6G offers ultra-fast internet speeds and low latency, allowing for real-time control of smart home devices, enhanced home automation, and more robust connectivity. The infrastructure required to support 6G is still under development, and early-stage implementation may be costly and slow. However, as global infrastructure evolves, 6G will enable fully connected smart homes with greater automation, personalized services, and enhanced user experiences. Regulatory concerns, environmental impacts, and long development timelines pose potential threats to its implementation.

AI 5.0 offers personalized environments, predictive health monitoring, enhanced energy efficiency, and improved security integration in housing. Despite these benefits, AI 5.0 faces high costs, complexity, and concerns over data privacy and user interface challenges. The growth of smart home automation, elder care solutions, and predictive maintenance offers promising opportunities. However, ethical concerns, hacking vulnerabilities, and rapid technological obsolescence present potential threats.

Grid 2030 focuses on intelligent power management, renewable energy integration, and improving energy efficiency and sustainability. However, high infrastructure costs and implementation complexity, as well as data security concerns, pose challenges. The growing demand for renewable energy, smart grid development, and global efforts toward sustainability present significant opportunities. Nonetheless, regulatory challenges, cybersecurity risks, and environmental unpredictability remain threats.

Hydrogen energy provides a clean, renewable energy source with versatile applications, helping to reduce carbon emissions. Despite its strengths, hydrogen energy faces high production costs, storage challenges, and infrastructure requirements. There is a growing demand for renewable energy, supported by government incentives, which presents opportunities for large-scale adoption. However, hydrogen energy faces competition from other renewable sources, safety concerns, and slow infrastructure development, which could impede its growth.

ESS enhances energy efficiency by managing peak loads, supporting renewable energy storage, and stabilizing the grid. However, high costs, limited storage capacity, and efficiency losses are key weaknesses. The increasing demand for renewable energy and advancements in battery technology present growth opportunities. Nonetheless, technological limitations, high capital investment requirements, and environmental concerns over battery disposal pose significant threats.

First, the strengths are as follows.

Advanced Technology Integration: The use of COBOTs, SCARA, and AI 5.0 enables increased efficiency in residential assistance, security, and health monitoring. Energy Efficiency and Sustainability: Technologies like Grid 2030, Hydrogen Energy, and ESS promote intelligent power management, renewable energy integration, and effective energy storage, contributing to a more sustainable future. Personalized Solutions: AI 5.0 and Smart Cell technology create customized living environments, improving the quality of life for residents through tailored services like health monitoring and energy efficiency. Digital Transformation: Digital Twins, VRM, and Cloud Computing provide innovative ways to manage buildings, design homes, and enhance user experiences through virtual environments and remote management.

Next, the weaknesses are as follows.

High Costs and Infrastructure Investment: Technologies such as Grid 2030, Hydrogen Energy, and ESS require significant investment in infrastructure and pose high implementation costs, which could hinder widespread adoption. Privacy and Data Security Issues: The use of AI, Face API, Cloud Computing, and IIoT raises concerns about data privacy, security, and potential vulnerabilities in connected home systems. User Interface Challenges: Technologies like Man-Machine Integration and AI-based systems might face challenges with user interface design, making them less accessible or harder to adopt for certain populations. Energy Efficiency Constraints: Smart materials like Smart Cell face challenges in terms of market coverage, durability, and energy efficiency, which could limit their scalability in the housing market.

Following that, the opportunities are as follows.

Growth in Renewable Energy Adoption: The global trend towards sustainability offers immense opportunities for Grid 2030, Hydrogen Energy, and ESS technologies to become foundational elements in future smart homes and energy systems. Personalized Smart Homes: With AI 5.0 and Smart Cell technology, there's an opportunity to expand personalized, energy-efficient, and health-monitoring solutions, improving residential welfare. Digital Twins and Virtual Reality: As digital transformation continues to evolve, the application of Digital Twins and VRM can further optimize building management, design, and remote home operations, creating more cost-effective and efficient housing solutions. Advancements in 6G and Beyond: The development of high-speed internet technologies like 6G will further enhance smart home connectivity, allowing more sophisticated data transmission, security systems, and automation in homes.

Lastly, the threats are as follows. Regulatory and Privacy Concerns: Increasing regulatory scrutiny over data privacy and cybersecurity may create barriers for widespread adoption of AI, Cloud Computing, and IIoT in housing applications. Technological Inequality: High costs and infrastructure requirements could create a gap between different socioeconomic groups, leading to unequal access to advanced housing technologies. Environmental and Market Uncertainties: The environmental impacts and market conditions around energy technologies like Hydrogen Energy and ESS may create unpredictable risks, including regulatory challenges or resource availability. Cybersecurity Threats: As housing technologies become more connected through AI, IoT, and Cloud Computing, the risk of cyber-attacks increases, which could compromise user privacy and system security.

In summary, while these technologies provide significant strengths and opportunities for revolutionizing housing welfare, they face considerable weaknesses and threats that need to be carefully managed for successful implementation.

Table 4: SWOT Analysis

echnology	Strengths	Weaknesses	Opportunities	Threats
COBOTs	Efficiency, residential assistance, elderly care, safety	High costs, user-friendliness, non-tech-savvy	Growing demand, assistive technologies, smart homes, elderly care	Technological inequality, high-income households, limited market penetration
SCARA	Automation, housing construction, reduced labor, productivity	Precision limitations, high costs, small-scale project	Automation integration, smart home solutions, scalability	Job losses, labor force resistance, automation
Face API	Enhanced security, personalized access, biometric identification, convenience	P Privacy concerns, data storage, misidentification risks, data management.	Post-pandemic growth in contactless access, smart homes, secure entry systems	Regulatory scrutiny, data privacy laws, limited adoption due to privacy concerns
Smart Cell	Home security, personalized access, identification, safety	Privacy concerns, biometric data, misidentification	Contactless access, post-pandemic growth, Face API, gated communities	Regulatory scrutiny, data privacy laws, limited adoption
DT	Building management, simulations, planning, monitoring, optimization, housing systems	Accurate data, implementation challenges, existing homes, digital infrastructure	Digital management, standard tool, housing infrastructure, optimization	High costs, data accuracy, development issues, slow integration, housing welfare
Man-Machine Integration	Smart home systems, intuitive interaction, responsive homes, occupant needs	Privacy concerns, complex user interfaces, tech-savvy challenges	Personalized smart homes, intuitive interfaces, accessibility, health monitoring	Cyber threats, data breaches, real-time data reliance, user input
VRM	Virtual housing design, customization, space visualization, planning	High costs, advanced hardware, limited accessibility, higher-end developments	Customizable housing, VRM technology, residential planning, virtual home tours, real estate	VR technology, realism, accessibility issues, user challenges with virtual platforms
Cloud computing, IoT	Smart home systems, real-time data, device connectivity, energy management, security, comfort	Privacy concerns, data storage, real-time monitoring, device compatibility, limited adoption	Smart cities, energy-efficient homes, cloud-integrated solutions, IoT-driven smart homes	Cybersecurity risks, data breaches, interconnected devices, smart home systems
6G and beyond	Ultra-fast internet, low latency, real-time control, smart home devices, home automation, robust connectivity	6G infrastructure, development, high costs, slow implementation	Fully connected smart homes, enhanced automation, personalized services, global infrastructure evolution	Regulatory concerns, environmental impact, long development timelines, cybersecurity risks
AI 5.0	Personalized environments, predictive health monitoring, enhanced energy efficiency, security integration	High cost, complexity, data privacy concerns, user interface challenges	Smart home automation, elder care solutions, adaptive interfaces, predictive maintenance	Ethical concerns Reliance on data integrity Hacking vulnerabilities Regulatory challenges Rapid technological obsolescence
Grid 2030	Intelligent power management, renewable energy integration, energy efficiency, sustainability	High infrastructure costs, implementation complexity, data security concerns	Growth in renewable energy, smart grid development, global push for sustainability, energy storage advancements	Regulatory challenges, cybersecurity risks, environmental unpredictability, high initial investments
Hydrogen energy	Clean energy source, renewable, versatile applications, reduces carbon emissions	High production costs, storage challenges, infrastructure requirements	Growing demand for renewable energy, government incentives, potential for large-scale adoption	Competition with other renewable energy sources, safety concerns, slow infrastructure development
ESS	Energy efficiency, peak load management, renewable energy storage, grid stability	High costs, limited storage capacity, efficiency losses, maintenance requirement	Growing demand for renewable energy, smart grid integration, advancements in battery technology	Technological limitations, high capital investment, regulatory challenges, environmental concerns with battery disposal.

5. Conclusions

The conclusion and policy implications of this study can be summarized as follows.

First, the conclusion of the study is as follows.

The application of Industry 5.0 technologies in residential welfare presents promising opportunities to improve the well-being and quality of life for individuals, particularly vulnerable groups such as the elderly and one-person households. These technologies—such as COBOTs, SCARA, AI, IoT, and energy management solutions—offer enhanced personalization, energy efficiency, security, and intelligent power management. However, the successful integration of these technologies faces several challenges, including high costs, data privacy concerns, infrastructure limitations, and technological inequality.

Industry 5.0 provides innovative, human-centric solutions that can address demographic shifts, such as aging populations and the rise of single-person households, by creating adaptive, responsive, and sustainable housing systems. Despite these advantages, issues related to data security, technological accessibility, and regulatory frameworks must be tackled to ensure equitable access and widespread adoption of these advancements.

Next, the policy implications are as follows.

First, Investment in Infrastructure: Governments and institutions should prioritize investments in digital and energy infrastructure to support the implementation of Industry 5.0 technologies in residential welfare systems. This includes developing smart grids, hydrogen energy solutions, and 6G networks to facilitate more advanced and efficient home systems.

Second, Regulatory Reforms: Policies must address data privacy and cybersecurity concerns, particularly regarding AI, IoT, and Face API technologies. Establishing strong regulatory frameworks can help mitigate risks associated with data breaches and misidentification while fostering public trust in these technologies.

Third, Technological Accessibility: Policymakers need to ensure that advanced housing technologies do not exacerbate inequalities. Programs should be implemented to make these innovations more affordable and accessible to low-income households, thereby preventing technological inequality from limiting access to essential services.

Fourth, Sustainability and Energy Efficiency: Renewable energy sources and storage solutions like Hydrogen Energy and ESS should be integrated into national energy policies. Promoting the use of clean energy technologies in housing can support global sustainability goals and reduce the carbon footprint of residential areas.

Finally, Collaboration and Research: Collaboration between the public and private sectors, along with research institutions, is essential for the continuous development and deployment of Industry 5.0 technologies in housing. This includes fostering innovation through funding and incentives for research and development in areas such as digital twins, VRM, and personalized smart homes.

By addressing these key areas, governments and institutions can leverage the potential of Industry 5.0 to create more resilient, inclusive, and efficient residential welfare systems for future generations.

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