Sustainable IoT Smart Home Perceptions Across Demographic and Vulnerable User Segments

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***Abstract*—The rapid expansion of Internet of Things (IoT) technologies has transformed smart home systems into essential tools for enhancing safety, independence, and quality of life, particularly for older adults and individuals with disabilities. However, the extent to which these groups understand and adopt IoT-enabled smart homes remains limited. This study addresses insufficient knowledge and uneven adoption of smart home IoT technologies among vulnerable demographic groups, examining how demographic factors shape levels of awareness and readiness for use. Two parallel approaches were employed for a validated questionnaire (of 15 sections) distributed to 249 participants and in parallel with semi-structured interviews for 25 selected individuals in Najran, Saudi Arabia, during the summer of 2023. Quantitative data were gathered and analyzed using descriptive statistics and multivariate analyses of variance. Qualitative data were under content analysis. Results revealed low levels of knowledge regarding IoT-enabled smart home systems among the respondents and different groups. Significant differences were found for groups of different employment status, age (15 to 30 and 30 to 45 years), economic status (above average), and disability status. However, no significant differences were found for gender or marital status. Qualitative insights indicated major concerns related to affordability, user passivity, lack of technical support, poor internet connectivity, device overload, issues of privacy, security, and system reliability. It was highly recommended to perform targeted measures to improve awareness, accessibility, inclusive design, and infrastructure. Future work may address spatial and temporal variations in IoT adoption, develop tailored training models for older adults and individuals with disabilities, and assess the effectiveness of policy initiatives aimed at increasing smart home readiness. These efforts can further improve the safe and effective integration of IoT technologies and improve indoor life quality and sustainability for vulnerable people.**

Keywords*—Internet of Things; smart home; vulnerable people; smart home; energy efficiency

I. Introduction

IoT has been significantly employed for establishing smart home technologies as a driver in promoting independence, safety, and quality, especially for vulnerable people (the elderly and disabled). Recent works have had a focus on the interactions of different groups of people with smart homes that are equipped with IoT. Previous works were addressed mainly on technical performance, attitudes of users, and infrastructure readiness of smart home systems, with limited attention paid to the most benefited by these systems, like vulnerable people. In the Saudi context, there is a lack of work exploring knowledge, awareness, and challenges faced by vulnerable people interaction with smart home systems. IoT applications have significantly transformed daily life by controlling various household equipment and devices, e.g., refrigerators and microwaves, into fully integrated smart home systems. The IoT model comprises a network of interrelated devices that connect and exchange data via the Internet. The network is connected with sensors, actuators, software, data storage, and processing units, enabling communication between devices and users, and also among devices themselves [1].

A. Smart Home Concept and System Design

Home automation has emerged after integrating IoT with home functions, improving the built and urban environments [2]. Smart homes provide users with real-time remote monitoring and control functions, and managing their living environments from anywhere with an internet connection [3]. These environments integrated artificial intelligence with IoT-enabled devices and automated features, improving domestic functions for better automation [4]. Beyond their domestic functions, smart home systems increasingly serve as key components within smart grid infrastructures, enabling real-time communication between users and electricity networks. This integration of energy efficiency and demand-response mechanisms thus improves the reliability of services and functionality [5].

The concept of smart homes dates back to the early 21st century, when advances in information and communication technology began to materialize not only in consumer electronics such as phones and televisions, but also in broader infrastructures such as urban networks and cities. This widespread technological integration has improved the quality of life globally, with significant impacts on home environments [6]. This work examined how factors such as gender, age, marital status, education level, income, and employment influence knowledge and perceptions of IoT-based smart home systems among vulnerable people. Furthermore, the study examines key barriers to adoption, including privacy concerns,

cost constraints, and system complexity, to inform the development of more inclusive and user-centric smart home solutions. With the ever-increasing proportion of older people and people with disabilities globally, this study highlights the urgent need to align smart home innovations with the specific needs of these often overlooked user groups.

The significance of this research lies in its focus on a user-centric perspective rather than a technology-based perspective, particularly in its emphasis on marginalized groups who face distinct cognitive, functional, and accessibility challenges in adopting smart technologies. These groups have limited benefits of using smart home system elements and functions due to a lack of awareness, usability issues, and a lack of trust in the technology. Existing studies tend to prioritize younger, more tech-savvy age groups, while neglecting the lived experiences and expectations of older adults and people with disabilities. By focusing on user perception and daily needs, this study categorizes smart technologies as tools for enhancing home comfort, safety, and well-being. Furthermore, this work provides vital insights for policymakers, technology designers, and developers seeking to create inclusive systems that protect user privacy, ensure ease of use, and meet the diverse needs of vulnerable populations. These findings are particularly relevant in the context of Saudi Arabia, where there is a lack of local research addressing the intersection of smart home technologies and demographic disparities. By identifying adoption gaps and concerns such as security and trust, the study contributes to the design of safer and more effective IoT systems for everyone.

Previous works have limited focus on the influences of demographic factors on cognitive disparities within vulnerable groups. For instance, privacy, cybersecurity, cost, technical support availability, and slow internet connectivity are frequently mentioned in global literature, but they have not been assessed in light of the living reality of Saudi families in the Najran region. This gap highlights the urgent need for studies that measure knowledge levels but also investigate demographic differences and contextual challenges affecting IoT adoption among older adults and individuals with disabilities. This work offers a comprehensive, multi-method investigation designed to provide evidence-based insights that can guide policymakers, technology developers, and service providers in developing more inclusive, accessible, and context-sensitive smart home solutions.

Home functions remain manual in many cases, even with technological advancements and availability. This misses valuable opportunities for simplification and automation, and thus high indoor quality [7]. The remote control capabilities of smart home systems also raise significant privacy and security concerns [8]. Many studies have reported discrepancies between the availability of smart home technologies and their adoption. For instance, South Korea and Malaysia still have limited awareness and a lack of trust, which has hindered uptake [8,9]. Research addresses that potential users, particularly homeowners unfamiliar with the benefits of smart technologies, are still unaware of their advantages [3,10]. This study explored how demographic factors influence knowledge and perception and identifying perceived risks and challenges in the adoption of smart home systems, with an emphasis on underserved populations in the Kingdom of Saudi Arabia. This work addressed the following research questions:

- What is the level of knowledge of the elderly and people with disabilities in using IoT in applying the smart home system to support their lives?
- Do factors such as gender, marital status, educational level, employment status, age, experience, class, and economic status affect knowledge towards using IoT in implementing a smart home system to support the quality of home life for the elderly and people with disabilities as users and potential users?
- What are the concerns and risks of using IoT for a smart home system to support the life quality from the perspective of the study sample members?

The smart home system has gained growing interest from ICT experts, initially focusing on automation and ambient intelligence [8]. Smart homes have progressed from basic appliance automation to systems integrating sensors and remote-control technologies that enhance efficiency and safety [10-12]. Today, smart homes utilize IoT and communication technologies to create intelligent, interconnected environments that reduce user effort and promote comfort and security [13]. Fig. 1 illustrates a conceptual diagram of the smart home system architecture consisting of the main pillars and applications.

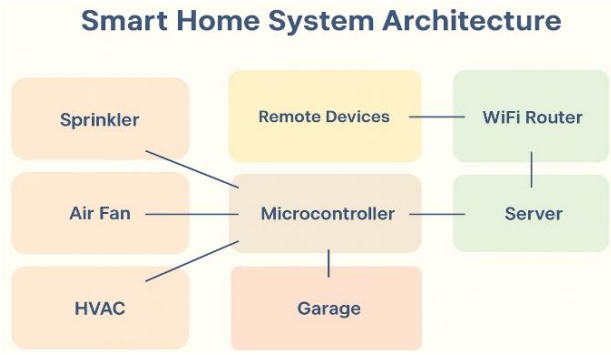

Fig. 1. Flowchart of the smart home system architecture that consists of main elements.

IoT systems provide easy communication among smart devices such as smartphones, microcontrollers, and sensors within the smart home system (see Fig. 1). This interconnected framework enhances home monitoring, security, safety, and protection through advanced IoT technologies [14]. A smart home is described by the convergence of various subsystems related to daily living, often supported by technologies such as fiber optic infrastructure that facilitate internal communication and external data exchange via a centralized smart portal. This integration creates a living environment that is efficient, comfortable, secure, convenient, and environmentally responsible, blending automation with service and management. The system employs computing technology, control systems, image display, and communication tools to meet the automation requirements of modern households [13]. Smart home controllers, which serve as central management units that transmit surpass traditional remote control functionality,

offering users control via smartphones, tablets, web browsers, and SMS [15] (see Fig. 2).

Fig. 2. Indoor smartness elements, connections and devices [7].

B. Advantages and Disadvantages of Smart Home Systems

Smart homes integrate advanced technologies and interconnected devices to enhance residents' quality of life. These systems operate by collecting and processing data through sensors and wireless networks, thereby creating intelligent environments that support a wide range of daily activities, including work, relaxation, and entertainment [8,16]. As smart technologies continue to evolve, smart homes offer increasingly personalized services that improve comfort, efficiency, and convenience [17]. A key contribution of smart homes lies in their positive impact on well-being, particularly through services that promote safety, support health care, and reduce household costs [18]. Environmental control is one of their defining features, enabling users to remotely or automatically manage lighting, thermostats, ventilation, and appliances, thereby minimizing manual effort and optimizing comfort [19].

Smart devices integrated into home systems are capable of detecting motion, alerting users to unauthorized entry, and providing access control through mobile apps, voice commands, or biometric verification [20]. These tools not only enhance security but also offer flexibility in managing access to the home. A smart home is a technology-enhanced living space that enables comprehensive control, monitoring, and support, significantly improving both safety and quality of life at home [21,22]. Users can manage security systems, energy consumption, environmental conditions, and even kitchen functions via smartphones and connected devices [9,15].

Recent developments reinforce this view: for example, AI-powered smart security systems now leverage IoT devices to provide real-time motion detection and authentication [23], while smart door locks integrate biometric authentication (e.g., fingerprint, face recognition) with IoT connectivity for enhanced access control [24,25]. Moreover, a meta-study on home automation security highlights the growing effectiveness of smart locks, motion sensors, and surveillance systems in improving residents' sense of security and control [26] (see Fig. 3).

Smart homes are often viewed as an impractical new technology due to their high cost and limited accessibility, as [27] points out. Smart homes allow users easy access to a variety of devices, including lighting, air conditioning, temperature sensors, and surveillance cameras, creating a more comfortable and secure living environment. The main concern is security and privacy. This concern arises because the data collected from these devices is typically transmitted to the user over an open network, such as the internet or a system provided by a service provider. Moreover, the involvement of service providers in collecting and storing this information raises the risk of data leakage and the potential for unauthorized access, leading to significant repercussions. For instance, the timing of an HVAC unit's operation could inadvertently reveal whether a homeowner is present or not. Similarly, any breach or tampering with critical medical data collected from wearable body sensors can have severe consequences, as articulated by [28].

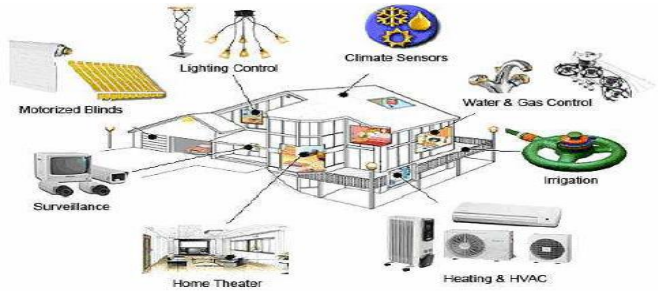

Fig. 3. Smart home integration services [15].

The elderly are people who have advanced in age and are starting to show signs of aging. Their definition varies from country to country. Some countries, such as Saudi Arabia, consider elderly people to be those who have reached the age of sixty and above, i.e., retirement age reported by the Ministry of Human Resources and Social Development, 2023. Other countries consider elderly people to be those aged sixty-five and above, or seventy and above. The elderly suffer from hearing and vision impairment, general weakness, wasting, decreased activity, and recurring illnesses, including chronic diseases. They need special care in employment, health care, social security, etc. [29]. Over the past four decades, models of disability have featured prominently in disability policy formulation, studies, and the human rights of persons with disabilities [30]. First, disability is a broad term that includes impairments and limitations in activities and participation according to the WHO (2010). Based on the 2006 United Nations Convention on the Rights of Persons with Disabilities (CRPD), disabled is referred to as a person with disabilities who have long-term physical, mental, intellectual, or sensory impairments that prevent them from fully and effectively participating in society on an equal basis with others, according to the United Nations, 2006. The high rates of disability are attributed to several factors, including advanced age, survival after birth, or injuries resulting from accidents.

C. Smart Homes and IoT for Elderly and Disabled Support

Quality of life broadly represents the well-being of individuals in society and is shaped by various personal and environmental elements, impacting physical, psychological, and social states [31,32]. In terms of individuals with disabilities, quality of life can be improved through the adoption of smart home systems powered by IoT technology. According to the Saudi Association of People with Disabilities (2021), the impact of IoT on home quality of life can be categorized into four domains: Being (physical and psychological well-being), Belonging (social inclusion), Transformation (personal growth

and leisure), and Daily Tasks (independent functioning). Addressing these domains through technology can significantly improve the daily life experience of individuals with disabilities and older adults [33]. The IoT refers to the network of interconnected devices equipped with sensors and software that enable remote monitoring and control [34]. These technologies allow users to control temperature, lighting, humidity, motion, and other elements in their smart home environment, improving comfort and safety.

Smart home technologies have become central to supporting active aging, independence, and adaptability among older adults, offering capabilities such as emergency response systems, accessibility features for individuals with visual and hearing impairments, fall-detection technologies, and even integration with wearable and implantable health-monitoring devices [6]. These developments align with broader societal efforts aimed not only at improving technical performance but also at creating intelligent living environments that enhance comfort, safety, and overall home life [11]. More recent studies reaffirm this trajectory, showing that AI-enabled smart home systems can significantly enhance health monitoring, daily functioning, and autonomous living for aging populations and individuals with disabilities [35,36]. In parallel, smart home ecosystems contribute substantially to energy efficiency and environmental sustainability, an aspect of particular relevance for older adults and people with disabilities who tend to spend more time at home. Solutions such as smart lighting, adaptive climate control, and automated appliance management help reduce energy consumption and improve residential energy performance [5,37].

However, barriers such as limited awareness, high costs, and a lack of digital skills hinder the spread of these technologies among these groups [17]. To overcome these challenges, it has recommended inclusive design practices and targeted educational initiatives to empower these groups [38]. Raising awareness and simplifying the use of technology can enhance adoption and participation in energy-saving practices, while also improving their quality of life.

A deeper critical analysis of previous research on the topic of the current study can be provided from the following aspects:

D. Demographic Factors and Their Impact on Knowledge

1) Age: Older adults often face challenges in adopting new technologies, including the IoT, due to a lack of technical expertise or a reluctance to learn new skills. They may also have concerns about ease of use and security.

2) Disability: Different types of disabilities can affect individuals' ability to interact with smart home systems. For example, people with visual or motor disabilities may have difficulty using traditional user interfaces, requiring more inclusive designs.

3) Education: Individuals with different educational levels may have different levels of knowledge about the IoT and its applications. Individuals with higher education tend to be more open to new technologies and better able to understand technical concepts.

4) Socioeconomic status: Individuals from different socioeconomic backgrounds may have different levels of access to the technologies and resources needed to adopt the IoT. Some individuals may not be able to afford the necessary equipment and services. Controversies and Contradictions:

5) Knowledge versus use: Some individuals may have theoretical knowledge of the IoT, but may be reluctant to use it in their homes due to concerns about privacy, security, or cost.

6) Use versus benefit: Some individuals may use smart home systems, but they may not fully realize the potential benefits they can offer, such as improved safety, comfort, or efficiency. Individual Needs: The needs and expectations of older adults and people with disabilities may differ, meaning that one smart home system may not be appropriate for everyone.

E. Quality of Life Impacts and Risks

Improving Quality of Life: Using the IoT in smart home systems can improve the quality of the life for the elderly and people with disabilities by providing greater independence, security, and comfort. For example, smart sensors can detect falls or other health issues and provide immediate assistance.

Privacy and Security Concerns: There may be privacy and security concerns when using IoT in the home, especially for individuals who have concerns about the collection or use of personal data. Technical risks: There may also be technical risks associated with the IoT, such as hacking or technical failures that could affect individual safety. These risks and concerns can be overcome through inclusive design. Smart home systems must be designed in an inclusive manner to meet the needs of diverse users, including the elderly and people with disabilities. Awareness and Training: Awareness and training programs should be provided to help individuals understand the benefits and risks of the IoT and how to use it effectively. Collaboration: Device manufacturers, researchers, and users must collaborate to set new standards for the design and production of safer and more inclusive smart home systems.

II. Methodology and Approaches

A. Study Methodology and Design

A descriptive approach was used using the survey method to describe reality quantitatively, which is the most appropriate and suitable approach for the nature of this study in answering its questions and achieving its objectives. The first study tool (knowledge questionnaire) was used to collect quantitative data and measure the level of knowledge about the use of IoT in smart home system implementation to support the quality of home life from the perspective of the elderly and people with disabilities as users and potential users. In addition, a qualitative approach was employed through semi-structured interviews to investigate the concerns and risks associated with the use of IoT in smart home system implementations, aiming to support the quality of life for the elderly and people with disabilities.

B. Study Sample and Demographic Distribution

A stratified random sample of (249) individuals from the elderly and people with disabilities categories was carefully selected from the Najran region in the Kingdom of Saudi Arabia

during the summer of 2023. This selection process was carried out in collaboration with the Candle of Hope Association for People with Disabilities and the Nour Najran Association for Women and People with Disabilities. The study tool was then distributed electronically through a Google Drive form, made accessible to the study participants. This electronic distribution was facilitated by cooperation with officials from the aforementioned organizations, who shared the questionnaire via personal email and the WhatsApp application. The questionnaire remained accessible for completion during the period of June 1 to 30, 2023. Table I presents a breakdown of the study sample, categorized by various demographic variables.

TABLE I. DESCRIPTION OF THE SAMPLE SIZE, ASSOCIATED DEMOGRAPHIC VARIABLES, INDICATOR, NUMBER OF SAMPLES (N), AND PERCENTAGE (%) (SEE ZEYAD ALSHBOUL [39])

Variable	Indicator	% (N)
Gender	Male	0.43 (106)
	Female	0.57(143)
Marital status	Married	0.43 (106)
	Single	0.57 (143)
Educational level	Illiterate	0.38 (94)
	School	0.36 (89)
	University	0.27 (66)
Employment status	Work	0.51(128)
	No work	0.49 (121)
Age	15-30	0.22 (56)
	30-45	0.28 (69)
	45-60	0.31 (76)
	+60	0.19 (48)
Experience	Likely to use	0.53 (131)
	Use	0.47 (118)
Classification	The Elderly	0.55 (137
	People with disabilities	0.45 (112)
Economic status	Average or below	0.50 (124)
	Above average	0.50 (125)
Total		100 (249)

A random sample of 25 participants was selected, including 10 elderly and 15 people with disabilities in the Najran governorate. This selection was conducted to obtain the most important concerns and risks related to the use of the IoT in the smart home system application to support the home quality targeted at vulnerable groups. This was done after the participants agreed to participate in the study, and the interview was recorded.

C. Tools of the Study

A questionnaire was developed to measure knowledge about the use of IoT in smart home system implementation to support home quality of life as perceived by the elderly and people with disabilities as users and potential users. To achieve this goal, reference was made to theoretical literature and previous studies relevant to the topic of the current study, such as the Saudi Society for People with Disabilities (2021) [6,33]. Appropriate items were formulated to measure knowledge about the use of the IoT in smart home system implementations to support home quality of life as perceived by older adults and people with disabilities as users and potential users. The tool, in its final version, consists of two parts. The first section consists of answer instructions and demographic information for the study sample members (gender, class, age, marital status, educational level, economic status, employment status, and experience). The second section of the questionnaire included (15) items designed to assess the level of knowledge related to the use of the IoT in implementing a smart home system, as perceived by the elderly and people with disabilities, whether as current users or potential users. To provide their answers, participants were asked to place a mark (√) in front of each item on a five-point scale that included options for strongly agree, agree, be neutral, disagree, and strongly disagree. To standardize the assessment tool, specific values were assigned to each response category, ranging from 5 for strong agreement to 1 for strong disagreement. The overall scoring system was then defined to be 1.00-1.80 for very low level, 1.81-2.60 for low level, 2.61-3.40 for moderate level, 3.41-4.20 for high level, and 4.21 - 5.00 for very high level [39].

D. Validity of the First Tool

This study utilized content and construct validity methods. Initially, the tool was reviewed by ten experts in computer science, networks, information systems, and psychological measurement from Saudi universities. They assessed item relevance, clarity, and alignment with the study's objectives. Items with at least 80% agreement were revised for clarity and measurability, resulting in a finalized 15-item tool. Construct validity was then tested using correlation coefficients between each item and the total score, based on an exploratory sample of 30 individuals from Najran. Results are detailed in Table II.

TABLE II. CORRELATION COEFFICIENTS (AT 0.05 SIGNIFICANCE LEVEL) BETWEEN THE ITEM AND THE TOTAL SCORE OF THE TOOL

Item no.	Correlation coefficient with the tool	Item no.	Correlation coefficient with the tool
1	0.67	9	0.33
2	0.57	10	0.53
3	0.44	11	0.57
4	0.34	12	0.36
5	0.50	13	0.51
6	0.60	14	0.77
7	0.57	15	0.73
8	0.56		

Table II presents the correlation coefficients for the items in relation to the overall tool, and these coefficients ranged between 0.33 and 0.77. It is important to note that all of these correlation coefficients were deemed acceptable and statistically significant, in line with the standards established in previous research [40]. Given the robust correlation coefficients observed, none of the items needed to be removed from the tool. This result further validates the tool's capability to accurately measure the intended constructs, reinforcing its overall validity and reliability.

E. Reliability of the First Tool

To verify the tool's reliability, two methods were used: test-retest and internal consistency. The tool was administered twice to 25 individuals with disabilities outside the main sample, and Pearson's correlation measured response stability. Additionally, Cronbach's Alpha was calculated to assess internal consistency. The results of both methods are shown in Table III.

TABLE III. CRONBACH INDICATOR FOR THE STUDY INSTRUMENT WITH THE NUMBER OF ITEMS, THE TEST USED, AND THE CRONBACH CONSISTENCY LEVEL COEFFICIENT

Tool	No. of items	Test-retest	Cronbach's Alpha
Knowledge questionnaire	15	0.88	0.79

The reliability assessment using the test-retest method yielded a coefficient of 0.88 for the tool as a whole. Simultaneously, when evaluating reliability through the internal consistency method, specifically utilizing Cronbach's Alpha, the tool as a whole produced a coefficient of 0.79. These reliability coefficients are notably high, signifying the tool's aptness for achieving the study's objectives. This strong reliability further bolsters the tool's capability to yield consistent and dependable results [40].

F. Semi-Structured Interviews

Semi-structured interviews were conducted with a group of 25 individuals, including 10 elderly people and 15 people with disabilities in the Najran region, who are users and potential users of the IoT in implementing a smart home system. The interviews targeted the most significant concerns and risks related to using IoT in smart home systems to support the indoor quality for targeted vulnerable groups. In this study, a semi-structured interview was used. It relied on a set of pre-defined questions, allowing the respondent to provide further clarification. The researchers developed a list of sub-questions that included the same items included in the study instrument (questionnaire), which received poor evaluation scores, to accurately identify concerns and risks related to the use of IoT in smart home environments to support the quality of home life for targeted vulnerable groups. The questions were as follows:

- In your opinion, is it possible to rely on IoT in implementing a smart home system to support the quality of home life for the elderly and people with disabilities now?
- In your opinion, do you think that using IoT in implementing a smart home system to support the quality of home life for the elderly and people with disabilities is convenient and facilitates daily tasks for the person?
- In your opinion, can IoT in smart home system applications maintain confidentiality, privacy, and security for the elderly and people with disabilities?

The validity of the interview tool was verified by a group of people with experience and expertise in the disciplines of computer science and networks, information and communications systems, and psychological measurement and evaluation in Saudi universities. After that, the interview tool was produced in its final version. The meetings were arranged with the participants in advance, and their consent was obtained to conduct the interview either face-to-face or remotely using the Zoom application. They were recorded manually and electronically (audio) and then transcribed manually on paper in the participant's words, leaving the interpretation until after the interview. Table IV shows the details of the interview.

TABLE IV. INTERVIEW DATA BY CATEGORY (THE ELDERLY, DISABLED), GENDER (MALE, FEMALE) AND NUMBER OF PARTICIPANTS, DURATION OF THE INTERVIEW, AND IMPLEMENTATION METHOD

Category	Gender	No.	Duration	Method
The elderly	Male	6	15-20 min.	Face-to-face at home
	Female	4	15-20 min.	Face-to-face at home
Disabled	Male	9	20-30 min.	ZOOM
	Female	6	20-30 min.	ZOOM

III. RESULTS

A. IoT Knowledge in Smart Homes and Indoor Quality

The first question: What is the level of knowledge of vulnerable people, IoT applications in smart home systems, to support the quality of home life from the perspective of the study sample members?

However, means, standard deviations, and rankings have been calculated based on the responses provided by the study participants regarding their level of knowledge regarding the use of IoT in implementing a smart home system aimed at enhancing indoor quality for elderly individuals and people with disabilities. The study targeted people as current users and potential users. The results of this analysis are presented in Table V.

The total score for the level of knowledge of IoT usage in implementing the smart home system to support indoor quality was with an arithmetic mean of 2.60 and a standard deviation of 0.77, at a low level of knowledge (see Table V). The means for the study tool items ranged between 2.51 and 2.68, with weak and moderate ratings. IoT in the smart home system application helps me communicate efficiently with others, such as maids and household workers [Item (15)] came in first place, with the highest mean of 2.68, a standard deviation of 1.08, and a medium level. IoT in the smart home system application helps me communicate with my family members efficiently and competently [Item (2)] came in second place. IoT applications need great tools and technologies to be used in the smart home [Item (4)], and IoT in smart home system application helps me to watch media in my home easily [Item (11)] have the same mean of (2.66) and level of knowledge. Items (6) "IoT in smart home system app makes it easier for me to transport purchases to my home myself" and (8) "IoT in implementing a smart home system requires highly qualified experts and specialists in the field of information and communications technology" ranked last with the same mean of 2.51 and the low level.

TABLE V. STATISTICAL DESCRIPTIONS OF KNOWLEDGE LEVEL IN APPLYING IOT IN THE APPLICATION OF A SMART HOME SYSTEM TO SUPPORT INDOOR QUALITY

No.	Items	Means	STD	Rank	Level of knowledge
15	IoT in the smart home system application helps me communicate efficiently with others, such as maids and household workers	2.68	1.08	1	Moderate
2	IoT in the smart home system application helps me communicate with my family members efficiently and competently	2.66	1.03	2	Moderate
4	IoT applications need great tools and technologies in order to be used in the smart home	2.66	1.17	2	Moderate
11	IoT in smart home system application helps me to watch media in my home easily	2.66	1.05	2	Moderate
3	IoT in smart home system applications is a major concern about maintaining security and privacy	2.63	1.04	3	Moderate
13	IoT application in the smart home system helps me go out and return to my home with ease and comfort	2.62	1.09	4	Moderate
14	Smart home can provide me with the ability to improve physical and psychological efficiency	2.61	1.04	5	Moderate
12	IoT application in the smart home system helps me navigate the corridors of the house with ease and comfort	2.59	1.00	6	Low
5	IoT applications in a smart home require basic computer skills	2.57	1.23	7	Low
10	IoT smart home system application helps me go to bed to sleep easily	2.57	1.01	7	Low
9	IoT in the application of the smart home system helps me to wear my clothes without relying on others	2.56	1.00	8	Low
7	IoT in the application of the smart home system helps me to enter the bathroom at home, relieve myself, and shower by myself without relying on other people.	2.55	0.95	9	Low
1	The application of IoT in smart home system requires connecting different facilities to the network to meet the automation requirements of the entire system and provide more convenient control and management.	2.52	1.16	10	Low
6	IoT in smart home system app makes it easier for me to transport purchases to my home myself	2.51	1.03	11	Low
8	IoT in implementing a smart home system requires highly qualified experts and specialists in the field of information and communications technology	2.51	0.93	11	Low
	Total score	2.60	0.77		Low

B. Demographic Features Impact on IoT Knowledge in Smart Home Systems

The second question: Do factors such as gender, marital status, educational level, employment status, age, experience, class, and income affect knowledge towards using IoT in implementing a smart home system to support the quality of home life for the elderly and people with disabilities as users and potential users?

To answer this question, the study calculated the means and standard deviations of the study sample members' responses. These responses are related to the level of knowledge in using the IoT in the context of implementing a smart home system aimed at improving the quality of life for the elderly and people with disabilities, whether as current or potential users. Data were further analyzed to examine differences based on factors: gender, marital status, educational level, employment status, age, experience, class, and income (see Table VI).

TABLE VI. MEAN AND STANDARD DEVIATION OF KNOWLEDGE LEVELS ABOUT USING THE IOT IN SMART HOME SYSTEMS TO SUPPORT THE QUALITY OF HOME LIFE FOR THE ELDERLY AND PEOPLE WITH DISABILITIES, ACCORDING TO DEMOGRAPHIC FACTORS [39]

Variable	Category	Mean±STD	N
Gender	Male	2.63±0.7	106
	Female	2.57±0.8	143
Marital status	Married	2.55±0.84	106
	Single	2.63±0.7	143
Educational level	Illiterate	2.51±0.8	94
	School	2.51±0.78	89
	University	2.84±0.65	66
Employment status	Work	2.79±0.6	128
	No work	2.40±0.84	121
Age	15-30	2.82±0.59	56
	30-45	2.84±0.64	69
	45-60	2.37±0.86	76
	+60	2.34±0.79	48
Experience	Likely to use	2.38±0.8	131
	Use	2.83±0.65	118
Category	The Elderly	2.33±0.79	137
	People with disabilities	2.92±0.6	112
Economic status	Average or below	2.27±0.8	124
	Above average	2.92±0.56	125

Responses varied significantly for level of knowledge about using the IoT in implementing a smart home system to improve the quality of life for the elderly and people with disabilities (see Table VI and Table VII).

TABLE VII. MULTIPLE ANALYSIS OF VARIANCE FOR LEVELS OF KNOWLEDGE ABOUT THE USE OF THE IOT IN SMART HOME SYSTEMS TO SUPPORT THE QUALITY OF HOME LIFE FOR THE ELDERLY AND PEOPLE WITH DISABILITIES BY DEMOGRAPHIC FACTORS

Source	Type I Sum of Squares	df	Mean Square	F	Sig.
Gender	0.168	1	0.168	.411	0.522
Marital status	0.267	1	0.267	.654	0.419
Educational level	5.749	2	2.875	7.036	0.001
Employment status	7.551	1	7.551	18.482	0.000
Age	8.154	3	2.718	6.653	0.000
Experience	4.128	1	4.128	10.104	0.002
Category	13.288	1	13.288	32.523	0.000
Economic status	11.558	1	11.558	28.289	0.000
Error	96.828	237	0.409		
Total	1825.371	249			

Differences of knowledge regarding the use of the IoT in implementing smart home systems to improve Indoor were not significant, whether they are current or potential users, when attributing the differences to gender or marital status (see Table VII). The F values reached 0.411 and 0.654, with significance levels of 0.522 and 0.419, respectively. In contrast, statistically significant differences appeared regarding the functional status, in favor of the working group, as the F value reached 48.218 at a significance level of 0.000. Statistically significant differences were also found for the experience variable in favor of the "use" category, with the F value reaching 10.410 and a significance level of 0.002. In addition, variation was observed according to the category variable, with the disabled category scoring higher (F = 32.523, p = 0.000). Economic status also showed statistically significant differences in favor of the upper-middle income group (F = 28.289, p = 0.000). Finally, both educational level and age revealed statistically significant differences in knowledge levels, with F values reaching 3.067 and 6.536, and significance levels reaching between 0.001 and 0.000, respectively. Differences were further examined through multiple comparisons approaches using Scheffe's method (see Table VIII).

Statistically significant differences at the 0.05 level for participants' responses regarding their level of knowledge of using the IoT to implement a smart home system to support the quality of home life for the elderly and people with disabilities as users and potential users (see Table VIII). This difference is attributed to the educational level between the university and school categories for the former, with the mean difference value of 0.33 being statistically significant (0.007). Significance levels were also found between the university and illiterate categories in favor of the university group. The mean difference value of 0.33 was statistically significant (0.007). Table VIII also shows statistically significant differences at the 0.05 level for participants regarding their level of knowledge of using IoT to implement a smart home system to support the quality of home life for the elderly and people with disabilities as users and potential users. This difference is attributed to age on the one hand; the age group (15-30) years, and both the categories (45-60) years and (over 60) years, in favor of the former. The mean difference values (0.44) and (0.47) were statistically significant at (0.002) and (0.003), respectively. On the other hand, there were differences between the (30-45) year group and both (45-60) year group and (over 60) year group in favor of the (30-45) year group. The mean difference values (0.46) and (0.49) were statistically significant at (0.000) and (0.001), respectively.

TABLE VIII. MULTIPLE SCHEFFE'S DIMENSIONAL COMPARISONS OF KNOWLEDGE LEVELS ABOUT THE USE OF THE IOT IN SMART HOME SYSTEMS ACCORDING TO THE VARIABLES OF EDUCATIONAL LEVEL AND AGE

Educational Level (I)	Educational Level (J)	Mean Difference (I-J)	Sig.
University	School	.33*	.007
	Illiterate	.33*	.007
Age (I)	Age (J)	Mean Difference (I-J)	Sig.
15 -30	(30 -45)	.02	0.999
	(45 -60)	.44*	0.002
	+ 60	.47*	0.003
(30 -45)	15 -30	.02	0.999
	(45 -60)	.46*	0.000
	+ 60	.49*	0.001

C. Concerns and Risks of IoT Use in Smart Home Systems

The third question: What are the concerns and risks of using IoT in implementing a smart home system to support the quality of home life from the perspective of the study sample members?

Interviews conducted with study sample members (n = 25), including (10) elderly people and (15) people with disabilities in Najran region who are users and potential users of the IoT in smart home system application, were analyzed. The interviews targeted the most important concerns and risks related to using the IoT in the smart home system application to support the quality of home life for the elderly and people with disabilities, from the perspective of the study sample members. Fifteen participants unanimously agreed that the most significant concerns regarding the use of the IoT in implementing a smart home system to support the quality of home life are due to the "high financial and material cost of implementing this system, which most people cannot afford". Twelve respondents agreed that, "this system may lead a person to lack flexibility and laziness as a result of heavy reliance on the smart home.", while (10) respondents indicated, "It is difficult to repair household faults because it requires highly skilled employees or companies specialized in this field". Eight respondents unanimously agreed that, "the availability of a fast internet network is weak in some areas or neighborhoods, which hinders the process of the home relying on it completely". Five respondents unanimously agreed that, "the enlarged size of networks and the increase in the number of devices in the smart home system may create a delay in response and processing time, which makes it difficult to manage real-time systems." One of the respondents stated, "The large number of devices using this system and setting different usernames and passwords for them may lead to complexity in using it and not meeting the needs of elderly people and people with disabilities".

The potential risks of using IoT in implementing a smart home system to support the quality of home life, (18) respondents unanimously agreed on "the ability of thieves to penetrate smart home networks to know the sleeping times of their residents to steal them". Sixteen respondents agreed that, "hackers were able to stop the heating system on harsh winter days or stop the air conditioning system on hot summer days, which may cause risks to the lives of the elderly and people with severe and multiple disabilities". Thirteen respondents unanimously agreed on "penetrating smart home networks may pose a risk to users' privacy, personal safety, and disclosure of their secrets". Eleven respondents unanimously approved that, "hackers are able to know the health status and devices used by elderly people and people with disabilities, which may cause real risks to their lives". Seven respondents agreed that, "hackers may exploit this system and manipulate energy consumption bills to increase or decrease them". Five respondents agreed that, "the possibility of stealing the personal data of the person using this system is very high, which leads to the theft of their bank accounts". Three respondents unanimously agreed that, "IoT users' data does not belong to them, and here lies one of the points of concern". "For example, if the user wants to unlock the door of his home upon arrival, his smartphone sends the command via the Internet to the cloud service responsible for locking the door, which in turn opens it, meaning that any potential hacking of the service will lead to real disasters that affect their privacy, confidentiality, and security". One respondent stated, "Logging into the home network through an IoT device and discovering their passwords used on the system enables thieves or hackers to launch a ransomware attack, rendering the IoT smart home unusable until money is paid".

IV. Discussion

Results showed that the overall degree of knowledge level of using IoT in applying the smart home system to support the quality of home life, as perceived by the elderly and people with disabilities as its users and potential users, is low. The result may be attributed to the use of different IoT devices in the smart home system. Each device has distinct features, features, and technical skills that participants possess, which affects their sufficient knowledge of this system, how to deal with it, and its importance in their lives. This finding is consistent with the findings reported by [41] in their study on IoT in South Africa, which revealed that technology cost and familiarity were the main factors inhibiting technology adoption, and the adoption of this system in particular. The findings could also be attributed to the level of awareness of the use of IoT in smart home systems. Lack of awareness about smart home devices is a major challenge for adoption, use, and potential by people [37] . The awareness level has been found low at different communities in Malaysia [9]. This work found that demographic factors such as gender and marital status did not significantly influence participants' knowledge of using IoT in smart home systems to improve the quality of life for the elderly and people with disabilities. This may refer to a shared awareness level and levels of satisfaction and experience in implementing IoT technologies in daily activities, regardless of gender or marital status. Men and women, across age groups and experience levels, appear to have similar challenges and levels of familiarity with IoT devices. Family members who provide care often assist in using these technologies, potentially contributing to equal awareness and usage across demographic groups. Significant differences emerged with employed participants who were showing higher levels of familiarity. This may have attributed to their greater exposure to the functional benefits of smart systems, particularly in assisting mobility, managing entry and exit from the home, and simplifying daily activities. There was high familiarity of using IoT systems by active IoT users, reflecting their positive contribution in sharing and enhancing awareness. Their experience with the unique advanced features of smart homes enabled them to become more independent and improve their quality of life [42]. Notably, individuals with disabilities demonstrated greater familiarity compared to older participants. This may be attributed to their adaptability in using IoT systems. This is different in case of older adults who may suffer from technophobia or face age-related challenges. Chronic illnesses or dementia may impact elderlies familiarity and confidence with smart technology handling [6].

Participants with above-average income have high knowledge. This may refer to their ability to afford these systems and their awareness level. Financial capacity may directly influence exposure and tendency to adopt smart home technologies. Educational attainment was another influential factor. Participants with a university education had higher levels of knowledge because they had access to information about emerging technologies, and it applications, and their ability to follow user guidelines. Higher education likely enabled them to appreciate the role of the IoT in improving daily life. Younger participants between 15 and 45 showed high knowledge and willingness level to be familiar with smart home systems. Their familiarity to technology and lower anxiety towards its use put them as more informed and likely users, both now and in the future.

Results revealed a wide range of concerns and risks in using IoT for smart home systems to support the indoor life quality for elderly individuals and people with disabilities. These concerns primarily associated with the costs of system implementation. Reliance in smart home systems may also reduce personal flexibility, while maintenance require highly skilled personnel or specialized companies. These factors limit users' independence. Moreover, inadequate availability of high-speed Internet may minimize full reliance on smart home technologies [43].

The high number of connected devices and low network capacity increase delay the response time, complicating the management of real-time systems. Data confidentiality remains another critical concern, as vulnerable people may expose users to theft, hacking, privacy breaches, manipulation of energy consumption, or even financial fraud [44]. Addressing these risks and concerns provides critical insights for government agencies and technology companies to develop efficient procedures and practices for safe and beneficial use of IoT-enabled smart home systems for elderly and disabled populations. The heightened awareness of these challenges among users further underscores the importance of educating them about the benefits, safe handling, and potential applications of smart home technologies.

The importance of adopting smart home technologies has been widely recognized, particularly for the elderly and individuals with disabilities. However, consumers are showing increasing interest in smart homes, although they face challenges related to acceptance and practical usage [45]. The role of IoT technologies in supporting independent living for older adults highlights the need for system designs that meet their specific needs [46]. Meanwhile, He et al. [47] examine privacy practices among smart home product development teams in China, highlighting the importance of complying with local regulations while balancing security and privacy concerns. These works showed that efficient adoption of smart home systems requires addressing challenges related to user acceptance, system design, and privacy protection, especially for vulnerable populations. The benefits of IoT-enabled technologies extended to smart waste management, and the vulnerable groups still have the opportunity to contribute to sustainable indoor practices[48]. For instance, smart trash bins have shown to be more efficient in terms of energy and waste management as a contactless device and hygienic method of disposal. Smart eco-friendly solutions and tools are key for improving indoor living quality and thus provide better sustainable practices [49].

This work provides an understanding of how smart home adoption unfolds among older adults and individuals with disabilities. While earlier studies have underscored challenges related to user acceptance, system design, and privacy protection, the current study advances this body of knowledge by revealing how these barriers manifest within real-life contexts shaped by demographic, economic, and accessibility factors. The identification of low levels of IoT-related knowledge combined with demographic disparities linked to age, disability status, employment, and economic conditions highlights the uneven landscape of readiness among vulnerable groups. This nuanced pattern contributes significantly to understanding why adoption remains limited despite the growing availability of smart technologies.

V. Conclusion

This work sheds light on the lived realities surrounding the adoption of IoT-enabled smart home technologies among older adults and individuals with disabilities. The study generates fresh insights into the subtle yet impactful barriers that shape adoption patterns within these vulnerable groups, barriers that extend beyond technical limitations to include issues of affordability, digital literacy, trust, and infrastructural reliability. These insights not only clarify why knowledge gaps persist but also illuminate how demographic variations intersect with personal experiences to influence perceptions and readiness for IoT use. Within this descriptive analysis, the findings naturally point toward important implications for the inclusive design of smart homes. By uncovering the specific needs, concerns, and usage restrictions of the participants, the study highlights design considerations that prioritize accessibility, user empowerment, and technological simplicity. Such considerations underscore the necessity of creating smart home ecosystems that do not merely incorporate IoT technologies but do so in ways that accommodate a wide spectrum of abilities, economic conditions, and age-related challenges.

The study provided evidence-informed trends that can support policymakers and technology developers in Saudi Arabia as they work to advance national digital transformation efforts. The patterns revealed in the data suggest opportunities to boost public awareness campaigns, tailor educational initiatives to users' digital capabilities, and encourage the development of IoT solutions that align with the principles of inclusive design. These observations carry practical relevance for national strategies such as Saudi Vision 2030, particularly in relation to improving the quality of life and expanding equitable access to emerging technologies. Finally, the descriptive insights generated by this research open pathways for future investigations that extend the inquiry across different regions and cultural contexts. Such work can enrich comparative understanding and deepen exploration of the practical benefits, risks, and user experiences associated with IoT-based smart homes, particularly for populations that remain underrepresented in the broader technology adoption literature.

VI. Study Limitations

This work is limited to Najran, Saudi Arabia and future works are encouraged to include more study areas for addressing special variations. Future works may be conducted at different time for better temporal variations of the responses, as this work captures responses at a single point in time. Finally, while the mixed-methods approach provides both breadth and depth, future research could incorporate longitudinal designs and larger, more diverse samples to validate and extend these findings.

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Ethical Approval

This work carries ethical approval from the Standing Committee for Scientific Research Ethics, Research Deanship of Najran University, Saudi Arabia. Reference No. of 010118-022124-DS. Accredited as a local committee by the National Committee for Bioethics at King Abdulaziz City for Science and Technology (HAPO-11-N-102).

Informed Consent Statement

Informed consent was obtained from all study participants.

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