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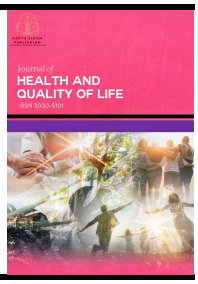

Advanced Technologies and the Elderly: Critical Enablers of Quality of Life

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ABSTRACT

The rapid advancement of technology presents a transformative opportunity to enhance the quality of life for the elderly. However, the adoption of such technology among older adults remains inconsistent due to many factors. Among the factors are psychological, social and technological barriers. Hence, the paper demonstrates the integration of advanced technologies act as a critical enabler in enhancing the Quality of Life (QoL). Through an integrative review of existing literature, this study identifies the technologies used by the elderlies and how it influences the QoL. The relations are clustered into four (4) key themes based on the relationship between the six (6) key technology domains and four (4) multidimensional domains of QoL. Findings underscore the role of technology in sustaining functional independence, psychological wellbeing, social connectedness and physical safety. By addressing the relations, advanced technology can be more effective integrated into senior living when it is designed based on the needs which help to foster a more connected and accessible environment for the aging population.

1. Introduction

The rapid growth of the global ageing population has emerged as one of the most significant demographic transformations of the twenty-first century. By 2050, individuals aged 65 and older are projected to represent 16% of the global population [1]. The advancement in healthcare, improvement in living standards and life expectancy have resulted in steadily increasing proportion of older adults. These improvements create new social, economic and healthcare challenges. Among the challenges is the need to ensure that elderly individuals can maintain independence, dignity and overall quality of life as they age. According to Al-Tamimi *et al*., [2], as demographics shift towards an ageing population, understanding and addressing the challenges associated with ageing becomes paramount for ensuring the wellbeing and independence of older adults. Traditional models of elderly care that often emphasize on institutionalization and reactive healthcare are insufficient in addressing the unique needs of older adults. As a result, there is a growing demand for innovative approach that support active ageing, independent living and holistic wellbeing. Studies highlighted

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the need for social support in areas such as caregiving, emotional support, adaptation of living environment, healthcare services, intergenerational assistance and technological solutions is increasing as the physical function deteriorate over time [3].

Advanced technologies have gained prominence as critical enablers of quality of life for the elderly. Digital technology holds significant potential in enhancing the well-being and social inclusion of older adults [4]. Technologies such as smart home systems, wearable devices, telehealth platforms and assistive technologies offer new opportunities to enhance healthcare access, improve safety, promote autonomy as well as strengthen social connectivity. In a study, conducted by Lewis (2004), [5] whereby the integration of advanced technologies, protocol and applications help to enhance the older people comfort and quality of life. Beyond supporting physical health, these technologies can also contribute to psychological wellbeing and social participation. Thus, when thoughtfully integrated into the elderly environment, advance technologies have the potential to transform ageing from a dependency living into an empowerment and active participation. Hence, this paper explores the role of advanced technologies as critical enablers of improving quality of life among the elderly by highlighting the contributions, challenges and implication for future elderly care living models.

1.1 Conceptualising Quality of Life (QoL) in Later Life

The concept of QOL is widely recognized in the literature as a multidimensional construct that encompasses of physical, psychological, social and environmental domains. QoL for the elderly extends beyond the absence disease and reflects an individual's perceived wellbeing, functional ability, autonomy and satisfaction with life within their context of living. The World Health Organisation (WHO) emphasizes the quality ageing is closely linked to maintaining functional ability through supportive environments. The supportive environment enables older adults to meet their basic needs, remain mobility, build relationships and continue to contribute to the society.

Existing literature also underscores the strong relationship between ageing, independence and overall wellbeing, where the ability to live autonomously plays a central role in sustaining dignity and life satisfaction among older adults. QoL frameworks applied in elderly living environments demonstrate that supportive physical design, accessible services and enabling technologies can significantly provide independence, thus enhancing the quality of life among the elderly. Al-Tamimi *et al*., [2] found that the accessibility of technology plays a significant role in enhancing the quality of life for the older adults. Environmental factors include the safety, accessibility and social infrastructure are viewed as equally important as health-related factors in shaping QoL outcomes. For instance, during the pandemic that occurred in 2019, digital technologies had become one of the instruments in reducing the adverse effects of social isolation and disruption to routine health [6]. Wang *et al*., [7] reported that the growing elderly population has raised significant concerns about their wellbeing, social integration and quality of life. Consequently, the QoL framework provide a valuable foundation for integrating living environment that is supported by appropriate technological and social system can promote holistic wellbeing.

1.2 Overview of Advanced Technologies for the Elderly

With the rapid development of information technology and the acceleration of global ageing, it becomes a defining feature of contemporary social transformation [8]. In the context of the elderly advanced technologies can be defined as digital intelligent and assistive systems that is designed to support health, independence, safety and overall quality of life. These technologies extend beyond

conventional medical devices and encompass integrated solutions that combine information and communication technologies, sensor-based systems and data driven platforms to respond to the unique needs of ageing populations. Many studies emphasize that the scope of advanced technologies in elderly care is not limited to clinical interventions but also includes everyday living support, environmental adaptations and social engagement. For example, innovations like Artificial Intelligence (AI), cloud computing, big data, wearable devices and Internet of Things (IoT) have been integrated into community services [9]. Thus, it positions technology as an enabler of active and independent ageing rather than merely a tool for illness management.

1.3 Challenges to Technologies Adoption Among the Elderly

With the rapid development of information technology and the acceleration of global ageing, older adults still face various challenges when using the technologies [10]. The major barrier to the adoption of advance technologies among the older adults is the consideration on the *cost and affordability* of the adoption. Malekmohamadi *et al*., [11] stated the progress of assistive technology is impeded by cost pressure. The high initial investment costs for the installation of the systems and coupled with the ongoing expenses for maintenance as well as system upgrades limit the accessibility on the implementation. The elderly will face a limited income as they aged, whereby most of them depend on their pension and retirement fund. Thus, study argue that without targeted financial support, subsidies of policy intervention, a technology enabled elderly living environments will widen the gap between the older adults who can afford those who cannot. Another challenge is *digital literacy* among the elderly. Many older adults experience difficulties in using digital technologies due to limited exposure, age-related cognitive or sensory and fear of making errors. In a study conducted by Backåberg e*t al*., [12], social obstacles such as limited digital literacy creates difficulties in adopting these technologies. Many literatures highlight that perceived complexity and lack of confidence significantly influence the technology acceptance.

Another widely discussed challenge is the *privacy and security concern*. Continuous data collection through sensors, cameras and health monitoring devices raises concerns about loss of privacy and misuse of personal information. Nielsen [13] highlighted technical challenges such as data security and privacy concern is one of the significant barriers to the implementation of technology among the older adults. Elderly users may feel uncomfortable with technologies that intrude into their private living spaces or collect sensitive health data without transparent consent mechanisms. Hence a robust ethical frameworks and data governance policies is needed to build the trust in using the technologies. Furthermore, the *resistance to change* influence technology adaptation among older adults. Studies show barriers such as generational resistance to technology hinder digital adoption among older population [14]. Many elderly individuals value traditional living arrangements, whereby they are face-to-face interaction and stick to their familiar routines. Thus, the literature stresses that successful technology adoption requires culturally sensitive, user-centered approached that respect elderly values while gradually introducing innovation that enhance the QoL.

2. Methodology

2.1 Research Design

This study adopted an integrative literature review methodology to comprehensively synthesise existing knowledge on advanced technologies as critical enablers of QoL among elderlies. An integrative review enables a broader understanding of complex and emerging topics as it allows the

review for diverse methodologies that help to capture the context, processes or even subjective elements to potrays the complexity of the topic and address the research question specifically [15]. In this study, a research question (RQ) is formulated to address the problem on the lack of advanced technology adoption in the senior environment, which is: What is the technologies adoption that can be used to act as the critical enabler to enhance the QoL of the elderlies.

A comprehensive literature search was conducted by using an established academic database such as Scopus. Scopus is widely recognized for their rigorous indexing standards and coverage of peer-reviewed journals. The search focused on studies published in English to ensure consistency in interpretation. Keywords and Boolean operators were systematically applied to capture relevant literature. The terms such as elderly, older adults, advanced technology, smart technology, digital technology, assistive technology, gerontechnology, quality of life, QoL, wellbeing and active ageing.

Clear inclusion and exclusion criteria were established to ensure relevance in quality of selected studies. Articled were included if they:

- Focused on elderly or older adult populations
- Examined advanced, digital or assistive technologies
- Addressed quality of life, wellbeing, independence or QoL domains
- Peer reviewed journal article

Studies were excluded if they did not focus on the following. The study selection process followed a staged screening approach. Initially, titles and abstracts were reviewed after literature search using Scopus database. The Boolean operators are used for the search and is filtered to English paper only a focusing on countries such as Malaysia, China, Hong Kong, Singapore, Australia and New Zealand. The total of 33 documents are retrieved. The titles and abstracts were reviewed to remove irrelevant of studies. After reviewing, the total of 22 documents are used and full text screening was conducted on the articles to ensure compliance with the inclusion criteria. Relevant data were systematically extracted using a structured matrix. This structured matrix is used to capture the key information such as authorship, year of publication, study objectives, technology type, methodology approach, QoL domain addressed, key findings and challenges.

2.2 Data Analysis

Data analysis was conducted using thematic synthesis. This allow patterns and relationship across studies to identified and integrated. Extracted data were coded and grouped into thematic categories that includes technology domain, QoL domain and the enabling mechanism. These themed were then synthesised to develop an integrative understanding on how advanced technologies function as critical enablers of QoL for the elderly.

3. Results

The reviewed studies demonstrate a substantial growth in research on advanced technologies for older adults. The growth is driven by the increase of global ageing trends and rapid advances in digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI) , smart home systems, wearable devices, robotics and digital health platforms. Table 1 below signifies the technologies ranged from low tech assistive devices to highly integrated advanced technologies and AI-enabled monitoring systems highlight by various authors:

Table 1
Advance technology used by the older adults

AUTHOR (S)	ADVANCED TECHNOLOGIES FOR ELDERLIES
Dermody *et al*., [16]	• IoT enabled sensors • Monitoring of activities of daily living i.e. movement and mobility, sleep and rest, medication adherence, hygiene and toileting, hydration and nutrition, fall detection and response • remote health monitoring systems • data dashboards and visualisation tools
Gao *et al*., [17]	• ICT • IoT • AI • AIoT • wearable sensors and sensors networks • smart home automation • Ambient assisted living technologies • machine learning & deep learning • intelligent building and building management systems • urban digital twins • smart city systems
Wong and Leung [18]	• Immersive Virtual Reality (IVR) using head mounted displays (HMDs) • 360 degree VR videos • Virtual nature environments (VNE) • Recreational and entertainment VR applications • Social VR platforms • VR enhanced therapeutic exercise (TaiChi) • VR combine with complementary therapies
Wu *et al*., [19]	• AI perception system • intelligent sensors • sit to stand assistance mechanism • anti-slip and stability mechanism • intelligent monitoring and adaptive adjustment
Chen *et al*., [20]	• smart cane with multi axis sensors • fall detection • GPS tracking • emergency SOS • health data synchronisation via mobile apps
Loo *et al*., [21]	• Wearable assistive technology (lower-limb exoskeleton–type aid) • Servo motors for thigh and calf lifting • Pulley–cable mechanism for leg lifting • Gas strut for knee stabilization during standing • Potentiometers for motion detection • Arduino UNO R3 microcontroller • Lithium Polymer (LiPo) battery • Lightweight structural materials (PLA prototype, Aluminum 6061)
Xu *et al*., [22]	• Long short-term memory (LSTM) deep learning algorithm • wearable sensors • computer vision and motion tracking • wireless communication systems • intelligent rehabilitation and monitoring platforms
Al-Tamimi *et al*., [2]	• Smart home technologies i.e. sensors, monitoring systems • Assistive technologies (AT) for daily living support • Robots with embodied intelligence (physical, interactive robotic systems) • Commercial off-the-shelf (COTS) devices

	• Middleware solution (WISE-WARE): • Intelligent integration layer that enables interoperability between multiple devices and supports health monitoring and personalised services
Chen and Phanumartwiwath [4]	• Internet and broadband services • Smartphones and tablets • Computers and laptops • Telehealth and e-health platforms • Online communication tools (video calls, messaging, social media) • Digital government and service platforms • Assistive and smart technologies (contextual discussion)
Su *et al*., [23]	• Assistive technologies (e.g., smart walking aids, smart beds/chairs) • Telemedicine and remote rehabilitation services • Digital health platforms (e.g., "Internet+ Nursing", "Internet+ Rehabilitation") • Artificial Intelligence (AI) applications for: - Early risk identification - Fall-risk prediction and monitoring - Precision health management
Kulkarni *et al*., [24]	• Portion plates and digital weighing scales (weight management) • Exercise bands and pedometers (physical activity) • Remote-operated plugs and torches (daily living independence) • Foot inspection mirrors, diabetic socks, moisturising creams (diabetic foot care) • Sleep masks and relaxation aids (mental wellbeing) • Educational materials and self-care guides
Li *et al*., [25]	• IoT mobile applications for diabetes management • Continuous Glucose Monitors (CGMs) • Smart glucometers • Smart pill dispensers • Wearable activity trackers • Dietary monitoring and nutrition apps • Remote monitoring and alert systems • Integration with healthcare provider platforms
Selvanesan *et al*., [26]	• Multifunctional mechanical design (transformable structure) • Assistive mobility and exercise features • Structural engineering and simulation tools: Autodesk Inventor (stress, strain, displacement analysis) • Sustainable material technologies: Aluminium & Mild steel • Universal design principles • Smart technologies are proposed as future enhancements but are not implemented in the current prototype.
Zhou *et al*., [27]	• Artificial Intelligence (AI) and generative AI (e.g. intelligent assistants) • Smart devices (smartphones, smartwatches, smart speakers) • Smart home systems • Robotics • Digital health technologies • Data-driven and adaptive systems
Wong *et al*., [28]	• Mobility aids: walkers, wheelchairs (tilt and reclining), quad cane • Transfer and positioning devices: transfer boards, stand-assist walker • Daily living assistive equipment: shower commode chair, commode with mobile pan, recliner/stand-up sofa • Safety and support devices: anti-slip seating mat, bed side guard

	• Non-intrusive sensor-based monitoring system (activity-based, indoor use)
Wirtz *et al*., [29]	• Artificial Intelligence (AI) and Generative AI (GenAI) • Intelligent Automation (IA) • Service robots • Voice assistants • Wearable devices and health trackers • Smart home technologies • Digital platforms and AI concierge systems • Augmented Reality (AR)
Oyegoke *et al*., [30]	• Smart home hubs (Amazon Alexa Echo Show, Google Nest Hub) • Smart doorbells (Ring, Google Nest) • Smart lighting (Wi-Fi-enabled LED bulbs) • Smart plugs • Automated curtain and blind systems • Supporting infrastructure: Wi-Fi routers and connectivity equipment & Smartphone-based control applications
Kang *et al*., [31]	• AI-enabled fitness trackers and smartwatches • Wearables with biosensors (e.g., activity, sleep, heart rate) • Data analytics and AI-driven feedback/recommendations • Smartphone integration for health monitoring
Wang *et al*., [32]	• Green infrastructure elements: - Public green spaces, gardens - Walking and cycling paths - Green walls and green roofs • Smart monitoring technologies (contextual integration): - IoT-based air quality monitoring - Ambient temperature sensing • Smart older adult care community systems integrating: - Environmental data - Health-oriented community planning
Gul *et al*., [33]	• Socially Assistive Robot (SAR): - Pepper robot • Key technological features involved: - Voice-based interaction - Tablet-based touch interface - Autonomous gestures (head, hand, eye tracking) - Pre-programmed conversational flow • Supporting technologies: - Robot Operating System (ROS) - Choregraphed (tablet interface programming)
Yu *et al*., [34]	• Smart seating systems (ergonomic, climate-adaptive, interactive) • Green spaces integrated with smart features • Accessibility-enhancing technologies: Digital kiosks, Voice-assisted systems, Real-time transit information • Sensor-based navigation systems: Wayfinding sensors, Obstacle and risk alerts • Supporting digital platforms and mobile applications embedded in urban public infrastructure
Sun *et al*., [35]	• Smart integrated devices (e.g. smart speakers, smart all-in-one devices such as Baidu Xiaodu, Xiaomi Xiaoai) • Devices with functions for: - Health monitoring - Information access - Communication and companionship

	- Daily life assistance • Internet-enabled digital platforms supporting these devices

From the study, it reveals that advanced technologies supporting the elderly can be clustered into six key domains. *Ambient assisted living system* utilises sensors, automation and monitoring tools to help in enhancing safety, support daily activities and enable ageing in place. *Health monitoring system* allows a continuous tracking of vital signs and physical activity of the elderly. This system facilitates early detection of health risks and proactive care management can be taken. Next is the *digital healthcare platform* that improves the accessibility to medical services. With the availability of this platform, it can overcome the mobility barriers of the elderly. Additionally, *mobility support technologies* enhance the functional capacity of the elderly. The elderly may face reduced physical limitation as they aged, thus with these technologies it can help in supporting their daily activities and promote independence. *Social connectivity technologies* such as video conferencing and digital social platforms play a crucial role in mitigating loneliness and encourage social participation among older adults. Further highlights of the importance of robust *digital infrastructure* as seamless connectivity and interoperable systems are essential for maximizing the effectiveness of these technologies. Table 2 summarise the findings that map to the six domains of technology categorization.

Table 2
Technologies domain

KEY TECHNOLOGY DOMAIN	ENABLING FUNCTION
Ambient assisted living system	IoT-enabled home sensors, ADL monitoring (movement, sleep, hygiene), smart home automation, intelligent building systems, non-intrusive indoor monitoring, service robots, AI concierge systems
Health monitoring system	Wearable devices, continuous glucose monitors, smart glucometers, fall detection, vital-sign tracking, AI-driven risk prediction, remote health monitoring dashboards
Digital healthcare platform	Telehealth and e-health platforms, telemedicine, remote rehabilitation, data dashboards, healthcare provider integration
Mobility support technologies	Task assistance (robotic) i.e. Smart canes, walkers, wheelchairs, sit-to-stand systems, lower-limb exoskeletons, anti-slip mechanisms, assistive seating, transfer devices
Social connectivity technologies	Social VR platforms, immersive VR experiences, voice assistants, socially assistive robots, smart speakers, video calls, digital companionship systems
Digital infrastructure	Seamless connectivity and interoperable systems with the availability of Broadband and internet services, smartphones and tablets, AIoT ecosystems, middleware platforms, smart city systems, urban digital twins, Wi-Fi connectivity

Quality of Life (QoL) has emerged as a multidimensional construct. It encompasses of physical health, functional independence, psychological (mental) wellbeing and social connectedness. Hence the six clustered technology domains collectively help to support the enhancement of QoL among the older adults. Table 3 highlight the relationship of the technologies used by the elderlies with the QoL domains.

Table 3
Relationship of the key technology domains and the QoL domains

KEY TECHNOLOGY DOMAIN	QOL DOMAIN			
	PHYSICAL (P)	FUNCTIONAL (F)	MENTAL (M)	SOCIAL (S)
Ambient assisted living system	/	/		
Health monitoring system	/		/	
Digital healthcare platform	/	/		

Mobility support technologies	/	/		
Social connectivity technologies			/	/
Digital infrastructure		/		/

Theme 1: Technology- Enabled Physical Safety and Health Maintenance

Technologies clustered under ambient assisted living systems, health monitoring systems, digital healthcare platforms and mobility support technologies consistently emphasize *physical* preservation. Ambient assisted living systems contribute to physical wellbeing through fall detection, safety alerts and non-intrusive monitoring. Indoor mobility that include activities such as sitting, standing and walking is important in maintaining overall wellbeing, especially those with mobility difficulties. The limited indoor mobility can lead to the risk of fall [36], thus with the technologies will reduce health risks within the living environment. Whilst, health monitoring systems enables continuous physiological tracking. The continuous physiological tracking contributes to early identification of health deterioration. Digital healthcare platform extend the capabilities by facilitating timely medical consultations while mobility support technologies enhance physical stability, movement and rehabilitation.

Theme 2: Sustaining Functional Independence and Autonomy

A dominant theme across the findings is the role of technology in supporting functional independence. Ambient assisted living systems enable older adults to perform activities of daily living safely, while mobility support technologies provide direct assistance with movement. Assistive technologies such as commodes, home care beds and reclining wheelchairs have emerges as solutions to address the specific needs of this population which help in overcoming the mobility limitations and directly improve the functional abilities [37]. Digital healthcare platforms help to reduce dependence on physical healthcare visits, allowing older adults to manage their health within familiar environments. Other than that, digital infrastructure underpins this theme by ensuring seamless system operation and interoperability. With the infrastructure, older adults able to interact with multiple technologies without excessive complexity. Thus, this theme underscores autonomy as a central objective of technology in ageing contexts.

Theme 3: Psychological Reassurance and Emotional Wellbeing

Technological interventions contribute to mental and psychological wellbeing both directly and indirectly. Health monitoring systems and digital healthcare platforms reduce anxiety related health uncertain by providing continuous access to care. Whereas ambient assisted living systems enhance feelings of safety and reassurance, particularly to those individuals living alone. Social connectivity technologies play a central role by addressing loneliness, boredom and social isolation. Older people who lives alone face significant challenges in maintaining emotional wellbeing [38]. They are prone to feel lonely and felt left out. Thus with the interactive platforms offered can help to reduce the feelings of being loneliness. Together, these technologies foster a sense of control, security and emotional engagement in which is a critical determinants of mental wellbeing in older adulthood.

Theme 4: Facilitating Social Engagement and Connectedness

Social connectivity technologies emerge as the primary contributors to the social dimension of QoL. Ageing people face significant psychological needs related to social connectedness and emotion

wellbeing [39]. Video conferencing tools, social platforms and interactive systems enable sustained communication with the family members, peers and caregivers. It enables the older adult to be socially engaged and can continue to be part of the society by participating in many events. The improved digital infrastructure will further supports this theme by providing reliable connectivity and access to digital social environments. Importantly, mobility support technologies indirectly enhance social participation by enabling older adults to physically access social spaces and community activities. Thus, this theme reflects the growing recognition that social engagement is integral to healthy ageing and cannot be separated from technological design considerations.

4. Conclusions

This study demonstrates that the integration of advanced technologies plays a critical role in enhancing QoL among older adults through multidimensional pathways. The findings highlight that the technology enabled physical safety and health maintenance are strongly supported through the combined application of ambient assisted living systems, health monitoring systems, digital healthcare platforms and mobility support technologies. These technologies collectively reduce health risks living environments, enable continuous physiological monitoring, facilitate timely medication intervention and support physical stability. Equally important, the findings underscore the role of technology in sustaining functional independence, psychological wellbeing and social connectedness. The advance technologies support older adults to perform daily activities safely and autonomously. It also reduces the reliance on to other services like caregivers, thus supporting ageing in place. Collectively, findings affirm that effective ageing solutions require an integrated technological system that can help to balance all the needs for the elderlies to stay relevant and active in life.

Despite these contributions, several limitation should be acknowledged. First, the study is primarily based on a synthesis of existing literature , which may not fully capture the real world implementation challenges such as the acceptance and digital literacy gaps. Secondly, the findings largely reflect technologically advances contexts, limiting the generalisability to resource constraint. Hence, future research should prioritise empirical investigation involving the end-users, caregiver and services providers to evaluate usability, effectiveness and ethical considerations of these technologies. Thirdly, based on the listed documents review, limited number of documents were obtained from Malaysia. It is suggested more research can be done to highlight the findings to match with the suitability with the local context.

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