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The Strategy for the Demand-Integrated Research and Development Network of Care Robots in Taiwan

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Abstract To address the needs of a super-aged society, the development of care robots requires engaging in experiential communication with users on both physiological and psychological levels to create service systems that effectively solve related challenges. This approach leads to a demand-integrated R&D network. This study explores the demand for care robots in Taiwan and identifies gaps in the development of R&D networks. It also examines Japan's experience in promoting care robot technology and proposes strategic recommendations that could assist Taiwan's development. The study yields three main implications. The first is to form a demand-integrated business ecosystem centered on the concept of clinical co-creation. The second is to establish a platform for integrating the needs of care robot technology to fill the gaps in the core technologies and service verification. The third is to pursue the acceleration of cross-ministerial connections between R&D and demand-side policies.

Keywords Care robots, super-aged society, demand-integrated R&D network, Taiwanese issue, Japanese experience

I. Introduction

Taiwan first reached the status of an aging society (with people aged 65 and above accounting for over 7% of the total population) in 1993 and subsequently became an aged society (over 14%) in 2018. Taiwan is expected to enter a super-aged society (over 20%) by 2025, and by 2070, the proportion of the elderly population will reach 43.6% (National Development Council, 2022). The

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transition from an aged society to a super-aged society in just eight years indicates that the speed of population aging in Taiwan will exceed the transition periods seen in developed nations such as Japan (11 years), the United States (14 years), France (29 years), and the United Kingdom (51 years), making it a rapidly aging society in the true sense.

The number of people in Taiwan needing long-term care will increase from 765,218 in 2018 to 1,003,043 in 2026 (Ministry of Health and Welfare, 2016). This includes various groups such as disabled elderly over 65, disabled persons under 50, disabled persons aged 50-64, disabled indigenous people aged 55-64, people over 50 with dementia, frail elderly, etc. From 2020 to 2023, 7.99% of Taiwan's population aged 65 and above were diagnosed with dementia. Based on population estimates, it can be inferred that the number of people with dementia aged 65 and above will be approximately 350,000 in 2024, reaching 470,000 by 2031 and potentially 680,000 by 2041, indicating an increasing trend in the dementia population (National Health Research Institutes, 2024).

In contrast, the number of formal care personnel, such as nurses and caregivers in Taiwan's general nursing homes, has been gradually increasing in recent years. Together with approximately 200,000 foreign caregivers, these personnel currently meet the demand for long-term care services. However, with the rapid economic growth in emerging market countries such as ASEAN (Association of Southeast Asian Nations), the number of foreign workers coming to Taiwan will inevitably decrease. In the long run, this will not be able to meet the rapidly expanding scale of long-term care demand.

Consequently, as Taiwan approaches a super-aged society, it will face medium- to long-term social issues such as expanding healthcare needs, insufficient care service personnel, and declining care service quality. This will further trigger problems such as increased social welfare costs and decreased productivity due to caregiver turnover, significantly impacting economic growth.

To address the socio-economic problems triggered by the super-aged society, it is imperative to upgrade care aids into robots and integrate them with IoT, cloud big data analysis systems, and AI to form a "care robot technology system," driving the development of a smart long-term care service society. As care robot technology becomes closely integrated with care service institutions, hospitals, and even community households, it can transform the workplace, attracting younger generations to care service jobs and enhancing professional service quality.

Although many Taiwanese companies have invested in care robot technology research and development for over a decade, two major issues persist. First, most academia-industry units approach care robot validation primarily from a technology supply perspective, focusing on finding suitable environments for validation. This often results in projects remaining at the Proof of Concept (POC) stage, making it difficult both to fully understand users' actual needs and to transition into widespread application. Second, even when care robots developed by these academia-industry units reach the commercialization stage, they lack robust R&D networks to continuously update and adapt to the dynamic changes in user demands.

Moreover, according to the Simple Life Table for Reiwa 4 and Healthy Life Expectancy in Reiwa 1 from the Ministry of Health, Labour and Welfare's statistical database, Japan entered a super-aged society since 2007 and will enter a super-super-aged society (with people aged 75 and above accounting for over 20% of the total population) by 2025. Japan faces more severe issues of rapidly increasing care needs and insufficient healthcare personnel. In response, Japan has become more advanced in the development and utilization of care robots. Notably, Japan has shifted its focus to a technology demand perspective in care robot technology development. It encourages users to actively collaborate with R&D units to co-create mechanisms that dynamically address actual needs. This approach serves as a valuable model for Taiwan to emulate.

Based on this background, this study aims to explore how Taiwan can learn from Japan's successful care robot strategies to establish R&D networks that promote the widespread adoption of care robots.

This study begins by defining care robots, followed by an analysis of their development trends and market demand in Taiwan, as well as the challenges in developing research networks. The study then examines Japan's care robot R&D promotion cases and their strategic implications for demand-integrated R&D network. Finally, it offers strategic recommendations for enhancing Taiwan's care robot research network development.

II. Definition and Scope of Care Robots

As the nation faces the most severe challenges of caregiver turnover and labor shortages in a super-aged society, Japan has become the most proactive country in promoting care robot technology. The Ministry of Economy, Trade, and Industry (METI) and the Ministry of Health, Labour and Welfare (MHLW) of Japan (2024) have categorized care robots into nine primary categories encompassing sixteen specific applications, including: transfer assistance robots (wearable, non-wearable), mobility assistance robots (outdoor, indoor, wearable walking support), excretion support robots, nursing surveillance and communication robots (for care institutions, home care, communication robots, etc.), bathing assistance robots, support robots for care services, functional training support, dietary and nutritional management support, and dementia life and care assistance. According to Kobayashi (2021) of Tokyo University of

Science, while people might imagine care robots to have human appearances, they actually serve various purposes and functions.

Furthermore, as societies age, the population of elderly individuals with dementia and mobility issues will increase rapidly. Therefore, the development and application of long-term care technologies using robots to care for elderly dementia patients, assist elderly individuals with mobility issues in bed transfers, and provide excretion and bathing assistance are considered crucial for future care services.

For example, in recent years, many elderly care institutions in Japan have introduced PARO, a communication robot resembling a baby seal, to care for dementia patients. PARO, developed by the National Institute of Advanced Industrial Science and Technology (AIST) and first sold in 2005, has been deployed in various elderly care settings, with over 3,000 units in operation. The robot is 57 cm in length, weighs 2.7 kg, and exhibits endearing expressions and movements like those of a live baby seal. It can learn to recognize and respond to its given name through repeated interactions.

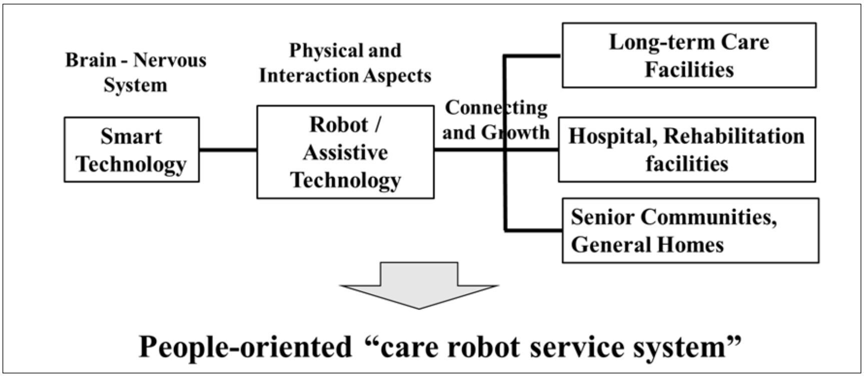
Another example is Robot Suit HAL, a walking support robot developed by CYBERDYNE. This wearable robot helps individuals with mobility issues by supporting the lower body during walking. HAL’s sensors detect electrical signals from the wearer’s body when they intend to move, assisting with knee bending and forward leg movement. Many elderly individuals with mobility issues have used HAL for walking rehabilitation, with some having regained walking ability after years of use. Care institutions are increasingly adopting HAL to help caregivers reduce their risk of injury during heavy lifting tasks, such as turning or transferring elderly individuals.

In 2011, the RIKEN-TRI Collaboration Center for Human-Interactive Robot Research developed RIBA (Robot for Interactive Body Assistance), a polar bear-shaped robot designed to assist with bed transfers for elderly individuals with mobility issues. RIBA weighs 180 kg and assists caregivers in transferring elderly individuals to and from beds. Using materials and structural design technology from Tokyo Rubber, it can lift patients weighing up to 61 kg, making it the world's highest-capacity care robot for patient lifting.

An example of an excretion and bathing assistance robot is the Muscle Suit, developed by INNOPHYS, a company established jointly by Tokyo University of Science and Kikuchi Manufacturing Co., Ltd. The Muscle Suits assists elderly individuals with toilet needs. The suit uses compressed air to power artificial muscles. When worn on the back and thighs, it aids caregivers in lifting and moving elderly individuals.

These examples illustrate how care robot technology has evolved from traditional aids like wheelchairs into automation and intelligence. It represents a type of electromechanical device that actively helps elderly or disabled individuals restore, maintain, or improve their living abilities. As shown in

Figure 1, care robots must function not only as physical devices but also integrate with smart technologies such as IoT and AI. This integration connects long-term care institutions, hospitals, rehabilitation centers, and households into a people-oriented care robot service system, expanding economic benefits from individual points to broader coverage.



Source: Compiled by authors.

Figure 1. The definition of care robotics

III. The development direction and problems of Taiwan's care robot R&D network

1. The Policies in Promoting Care Robot Technology in Taiwan

In 2010, Taiwan's Board of Science and Technology (BOST) under the Executive Yuan convened the Smart Automation Industry Development Strategy Meeting (SRB Meeting) to gather insights from various stakeholders. The meeting concluded with the recommendation to "develop innovative applications of service robots to expand niche markets", emphasizing the importance of robot technology in service industries. Subsequently, multiple policy initiatives were implemented to promote the development and application of service robot technology. However, these efforts remained predominantly at the research and development prototype stage, lagging behind industrial robots that had achieved commercialization and industrialization. Within service robots, care robot technology development was particularly nascent. It was limited to exploratory research by suppliers—companies or research institutions— and lacked a co-creation mechanism between technology suppliers and healthcare service users.

In September 2015, BOST proposed the concept of “assistive technology R&D and industrial development” at the 3464th Executive Yuan Council Meeting. The initiative aimed to promote a cross-ministry integrated model of industrial development characterized by “creativity + prototyping + commercialization”. This strategy sought to accelerate the development of advanced assistive devices and the expansion of smart healthcare service systems. However, assistive technology at this stage mainly followed traditional operational modes. The prospects remained uncertain for evolution into systems where devices could either collaborate with caregivers or independently serve care recipients.

In June 2009, Taiwan’s Ministry of Economic Affairs (MOEA) approved the “Development Project for Home Companion Robots for Middle-Aged and Elderly Groups”. This initiative marked the first integrated industrial project in the domestic service robot domain. Under this MOEA-funded technology research project, the Industrial Technology Research Institute (ITRI) developed the Lightweight Mobile Assistance Robot, demonstrating significant progress in care robot technology. This robot provides power to the hip and knee joints for individuals with spinal cord injuries, surpassing traditional assistive devices that only offer lower limb fixation. This innovation facilitates easier transitions between walking and sitting, enabling users to traverse flat surfaces, slopes, and stairs. The research team behind this project has since established an independent enterprise, with investment from major domestic electronics firms.

Furthermore, in December 2016, the Ministry of Health and Welfare (MOHW) approved the Long-Term Care Plan 2.0 (LTC 2.0). The LTC 2.0 policy framework was enhanced in December 2017 by the Long-Term Care Benefit and Payment Standards, which provided subsidies for assistive devices and home accessibility improvements. These measures aimed to maintain elderly people's daily activities, slow their physical decline, and create safer living environments. However, the subsidies were limited to basic personal assistive devices, excluding smart care robots with advanced functionalities.

Currently, MOEA's policies on smart robot development prioritize industrial robots and smart manufacturing. Efforts to promote the R&D and commercialization of care robots have included technology-specific projects and the establishment of safety standards aligned with international norms. Nevertheless, these initiatives have neither extended care robot applications to smart healthcare systems nor established comprehensive R&D and industrialization policies. Similarly, while the MOHW’s Long-Term Care Plan 2.0 has provided subsidies for basic assistive devices, it has not extended support to smart care robots and intelligent care systems.

2. Trends in Taiwan's Development of Care Robot Technology

At present, Taiwan's manufacturers and research institutions are primarily in the stages of prototype development and market application testing for care robots, with widespread adoption yet to be achieved. Care robots currently deployed in medical or caregiving services include health education robots, group activity assistance robots, medical instrument transport robots, and smart medical cart robots (mobile nursing stations). These robots are generally based on modified service robots originally used in shopping malls or logistics environments, thus falling under the category of indirect care robots. Their primary purpose is to alleviate the routine workload of caregiving staff. However, the commercialization of these indirect care robots in recent years has fostered greater awareness and willingness to adopt care robots in medical and caregiving services. This progress has paved the way for the broader adoption of direct care robots that involve extensive human interaction.

2.1 U-Van Intelligent Transport Robot by Chang Gung Medical Technology[1]

Chang Gung Medical Technology (CGMT), in collaboration with Chang Gung Memorial Hospital (CGMH), developed the U-Van Intelligent Transport Robot in late 2016. This robot is designed to transport surgical instruments, medical supplies, and medications across operating rooms, pharmacies, and supply rooms. This robot reduces the physical burden on medical staff and allows them to dedicate more time to patients care. U-Van features CGMT's proprietary path-scanning and map-drawing software, enabling it to learn routes, avoid obstacles and people, and calculate the optimal delivery paths. The company continues to develop diversified intelligent medical transport systems in collaboration with CGMH, incorporating features such as multi-robot dispatch centers, wireless elevator operation, and driving safety recording, aiming to improve service efficiency and quality in hospitals and long-term care facilities. However, these robots continue to face operational challenges in human-machine coordination. Consequently, their adoption in medical and caregiving settings remains limited even beyond 2020.

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1 On August 9, 2018, the author conducted an interview with the Operations Director of Chang Gung Medical Technology and subsequent follow-up.

2.2 Free Walk Exoskeleton Robot by FREE Bionics Taiwan[2]

FREE Bionics Taiwan originated from a robotics R&D team within ITRI's Mechanical and Mechatronics Systems Research Laboratories. The team developed the Free Walk exoskeleton robot in 2012 to assist elderly individuals with spinal injuries in walking and rehabilitation. After spinning off from ITRI as a startup in 2017, FREE Bionics Taiwan collaborated with USCI Japan to conduct clinical trials of the Free Walk robot in Japanese healthcare institutions. The robot’s weight has been reduced from 27 kg to 20 kg, and its single-leg width has been narrowed from 10 cm to 7 cm, enhancing walking stability and reducing user arm strain. This significantly improves usability, allowing spinal injury patients to independently wear the robot, stand up from wheelchairs, and perform actions like walking straight or turning. FREE Bionics aims to facilitate patients’ social reintegration by enabling their independence and reducing caregiver burden. The company emphasizes that true reduction in caregivers’ workload can only be achieved when the robot allows patients to perform some tasks that they were previously incapable of, such as walking, rather than merely assisting with physical movements or repositioning. In 2022, the company leveraged Free Walk's joint movement technology to develop the NimBO Muscle Strength Trainer, a joint mobility training device. This device is specifically designed for rehabilitation training of patients with various conditions including: sarcopenia, degenerative arthritis, post-orthopedic surgery conditions, and nerve injuries. This development demonstrates that care robotics extends beyond individual technological advances to create comprehensive solutions addressing the elderly's evolving needs.

2.3 Excretion Assistance Robot by EVERGET TECH[3]

EVERGET TECH has actively developed an excretion assistance robot named the Excretion Assistance Robot. This device detects and responds to patients’ defecation or urination in real time, immediately absorbing waste, cleaning, and drying. It minimizes the risk of elderly patients falling while attempting to use the restroom and helps prevent pressure ulcers or infections. This robot also alleviates the stress and physical burden on caregivers required to move bedridden patients. EVERGET TECH proposes two key development directions for Taiwan's care robot technology. First, traditional assistive devices should integrate intelligent features through sensor-based data collection and

2 On April 17, 2018, the author conducted an interview with the Chairman of FREE Bionics Taiwan and referenced Jocelyn (2023).

3 On May 13, 2018 and December 17, 2024, the author conducted interviews with the Chairman of EVERGET TECH.

cloud computing analysis, thereby addressing current limitations and improving service quality. Second, industrial robots should undergo miniaturization and functional specialization to facilitate commercial production. Currently, care robots serve as functional tools that address the partial needs of elderly individuals or reduce the excessive workload of caregiving staff. As adoption increases, development will shift toward multi-functional care robots capable of addressing diverse needs. The company noted that high costs and pricing challenges have kept direct caregiving robots primarily at the proof-of-concept stage, limiting their widespread application.

2.4 AI Companion and Communication Robot by NUWA Robotics[4]

In 2024, the Hsinchu Branch of the National Taiwan University Hospital collaborated with NUWA Robotics to introduce Kebbi Air, an AI companion and communication robot addressing long-term care challenges for the elderly. This care robot integrates AI with flexible physical operations, featuring functions such as: reception and guidance services, real-time conversation, capability, autonomous charging, and obstacle avoidance. Elderly users can interact with the robot through voice commands and touchscreen operations, enabling self-assessments to help identify potential health issues early, thereby forming personalized healthcare services. Furthermore, the robot incorporates skeletal detection technology to present rehabilitation activities in the form of games, increasing the elderly's willingness to participate and reducing the fatigue of caregivers caused by repetitive tasks. The Hsinchu Branch of the National Taiwan University Hospital aims to continue its collaboration with NUWA Robotics. Their goal is to develop companion robots that healthcare professionals can program without technical knowledge, thereby providing advanced and thoughtful care for the elderly.

3. Demand direction and development status of care robots in Taiwan

Based on this study's survey of experts from Taiwan's industry, academia, and research sectors regarding care robots[5], the primary types of care robots that should be encouraged for adoption in long-term care institutions, hospitals, and

4 Reference the content reported by the Hsinchu Branch of National Taiwan University Hospital (2024).

5 In 2018, the author conducted an expert questionnaire survey titled "Development Strategies for Care Robot Technology to Address the Problems of a Super-Aged Society" with 20 industry, academia, and research experts who have experience in promoting the development of care robot technology.

general households over the next eight years, in order, are communication robots, support robots to assist caregivers, transfer care robots, mobility assistance robots, and remote medical consultation robots. Respondents identified two main challenges that care robot adoption could address over the next eight years: addressing the caregiving labor shortage and workload issues, and promoting elderly independence. This suggests Taiwan's care robot development should focus on intelligent functions that support dementia patients' daily needs, reduce caregiver burden, and promote elderly independence.

Expert opinions indicate that Taiwan's care robot technology remains primarily in the research prototype and market testing stages, without achieving widespread adoption[6]. The main factors include insufficient clinical validation sites, high manufacturing costs, the inability to accurately address changes in user needs, and the lack of standardization in human-robot collaborative service models.

Care robots currently deployed in medical and care settings primarily serve three functions: companionship and communication, medical equipment transportation, and smart medical cart operations. These types of robots are often improved versions of service robot technologies originally used in retail or logistics settings and can be categorized as indirect care robots. They serve two primary purposes: reducing staff workload and providing emotional support for elderly individuals. The successful commercialization of these indirect care robots has increased the acceptance of robotic solutions in healthcare settings. This acceptance has facilitated the development of direct care robots requiring more intensive physical human interaction.

Many Taiwanese companies have actively invested in direct care robots that involve physical human contact. These companies include major precision machinery manufacturers, electronics companies, and startups. Several of these products have successfully completed clinical trials and entered commercialization. The types of direct care robots developed by Taiwan's academia, industry, and research sectors in recent years include exoskeleton robots for rehabilitation, walking support robots, and assistive robots for toileting.

Table 1 summarizes expert opinions regarding the future development directions and challenges for care robots in Taiwan.

6 In addition to the results of the expert survey, this study also conducted interviews with the related industry representatives in Taiwan in December 2024.

Table 1. Demand directions and problems in developing care robots in Taiwan

Classification	Description
Development purpose	Reduce the "disabled population" of the elderly and help the elderly rebuild or maintain their ability to live independently. Use the time of medical and nursing staff effectively and return it to the people being cared for. Reduce the heavy labor burden and manpower shortage problems of caregivers.
Demand direction	It has the functions of self-debugging and connecting to the Internet, and could be connected with software and hardware to build a smart long-term care service system. Easy operation, quick wearing, weight-bearing and other functions. Gradually move from partially functional robots to all-round robot development. It has the function of responding to patients with dementia. Humanized characteristics and softness of human-machine interface. The intelligence of traditional assistive devices.
Development issues	The collaborative service model between humans and care robots has yet to take shape. There is a lack of service verification platforms providing clinical trials for care robots. High development costs, coupled with personnel training expenses, further affect sales or rental prices. Few manufacturers are developing robot products tailored to the needs of dementia patients. Limited awareness of care robots among end users makes promotion challenging. Regulations, design standards, and safety evaluation methods for care robots remain underdeveloped, leaving developers without clear guidelines, resulting in inconsistent product quality and low market acceptance.

Source: Compiled from authors' interviews.

4. The development direction and problems of Taiwan's care robot R&D network

The key domestic members expected to contribute to Taiwan's care robot R&D network development include, in order of importance: care robot system integrators, domestic care robot or smart assistive device manufacturers, large enterprises' medical care robot R&D centers or departments, government research think tanks, key component manufacturers for care robots, startup companies and research communities related to care robot application services, and care robot validation fields (such as care robot validation service centers in colleges and universities related to medical care, care robot experience and display centers in various counties and cities, etc.).

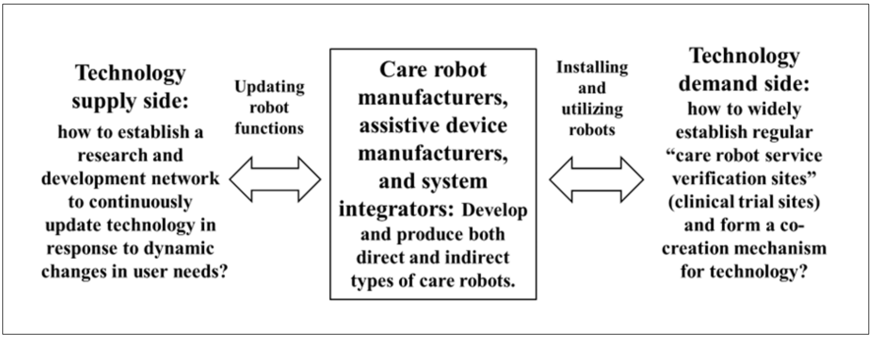
Consequently, establishing an integrated communication platform between care robot technology suppliers and users is crucial. This platform would facilitate collaboration between supply-side stakeholders (manufacturers, component suppliers, and research institutions) and demand-side providers (verification facilities and software development communities). This collaborative approach is fundamental to establishing an effective care robot R&D network.

For indirect care robot R&D network development, these robots will function as communication platforms connecting care professionals with elderly individuals. This requires continuous integration of smart care service applications. Successful implementation requires close collaboration among academic and research institutions, innovative tech teams, and the information management departments of healthcare institutions. Only by forming a development community for care robot application service software can this goal be realized.

For direct care robots, which have a higher degree of human interaction, manufacturers developing these robots also need to act as system integrators. These robots provide both care and rehabilitation functions, requiring customization to address specific disability symptoms and caregiver needs. Therefore, R&D personnel must monitor real-time usage conditions to develop systems that meet actual service needs.

The development of direct-care robot R&D networks requires special attention due to the robots' intensive physical and mental interaction with users. This development requires sustained collaboration with healthcare institutions to observe and analyze long-term robot usage by elderly individuals and caregivers. These observations enable continuous improvements in functionality and safety design. A key priority is encouraging healthcare institutions to establish regular care robot clinical trial sites. These sites should facilitate collaboration between institutions and manufacturers to develop products that meet actual user needs.

Figure 2 illustrates the key challenges and development gaps in Taiwan's care robot R&D networks.



Source: Compiled from authors' interviews.

Figure 2. The gaps in the development of Taiwan's care robot R&D network

IV. Case Study on the Construction of Japan's Care Robot Development Network

Japan entered a super-aged society in 2007 and is projected to become a super-super-aged society by 2025. This demographic shift presents complex societal challenges due to the increasing number of dementia patients. This has positioned Japan as a global leader in developing care robot technology. This study examines how Japan established its R&D network for care robot development.

1. The Case Study of Toyota's Human Support Robot[7]

Toyota Motor Corporation initiated the development of the Human Support Robot (HSR) in 2012. This care robot was created to coexist with family members and provide various life support functions in the home environment. Toyota's staff stated that for HSR to live with humans, it must have three features: small size and lightweight, safety and security, and easy operation. HSR should also perform three primary functions supporting elderly independence: "picking up," "fetching," and "remote control." HSR assists elderly individuals with mobility difficulties in their homes or care institutions and supports remote operation by family members or caregivers, aiming to achieve more comprehensive life support in the future. The R&D network driven by HSR

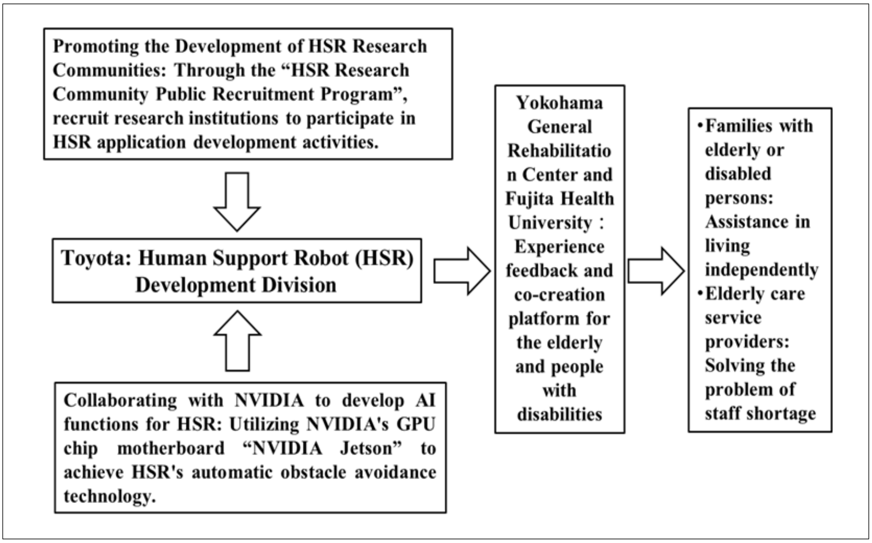
7 On April 23, 2018, the author conducted an interview with the Life Support Robot Development Team at the Global Planning Office, T-Frontier Business Division, Future Creation Center, Toyota Motor Corporation, and referenced Intelligent Home Robotics Research Committee (2022).

includes three aspects: promoting the development of care service verification fields, promoting the development of industry-academia collaborative R&D communities, and collaborating with top overseas AI companies (see Figure 3).

First, to develop a care service co-creation verification platform, Toyota Motor Corporation partnered with the Yokohama Rehabilitation Center and Fujita Health University during HSR development. They conducted empirical studies on HSR usage by elderly and disabled persons in both institutional and home settings. Through feedback from direct users and real-time collection of care robot motion data, they further improved the design of HSR. This initiative transformed local rehabilitation and elderly care education institutions into care service verification platforms, establishing a clinical co-creation mechanism between manufacturers and users.

Secondly, to promote industry-academia R&D collaboration, Toyota Motor Corporation formed strategic alliances with academic institutions to accelerate HSR's practical applications. They formed the HSR R&D Community to advance software technologies for the robot. Toyota provided academic institutions with the latest robot models, enabling them to develop and improve software that enhances performance and adds new service functions. The company also provided research funds to community members with promising collaborative R&D results to deepen software technology development. All community members shared development outcomes, including application software and service models, thereby accelerating technological advancement. In 2022, Toyota Motor and the Robotics Society of Japan restructured the HSR R&D Community's operation. These changes enhance researcher collaboration and accelerate progress through improved outcome sharing.

Finally, in terms of cooperation with overseas AI companies, Toyota Motor Corporation began collaborating with NVIDIA in 2016, using NVIDIA’s custom GPU chipboard, NVIDIA Jetson, for robots and drones on HSR. This implementation enabled autonomous driving and obstacle avoidance technologies developed by Toyota’s U.S. AI research subsidiary, TRI. This chipboard significantly enhances the development of robots or drones that utilize deep learning, benefiting the advancement of AI-equipped care robot technology.



Source: Authors' interview.

Figure 3. The R&D network driven by Toyota's Development of the Human Support Robot (HSR)

2. The Case Study of Social Welfare Corporation Zenkoukai[8]

Zenkoukai's director Miyamoto indicates that Japan's elderly social welfare facilities must transform into internationally competitive, high-quality care service enterprises. The integration of care robots and AI technology into smart long-term care services becomes crucial in this transformation.

In August 2013, Zenkoukai established the Care Robot Laboratory to start developing and introducing various care robots and AI application service systems in collaboration with external manufacturers. Prior to establishing the laboratory, Zenkoukai had introduced CYBERDYNE's Robot Suit HAL in November 2009 for testing. They worked with the University of Tsukuba and CYBERDYNE to improve the exoskeleton robot specifications to meet the actual needs of elderly individuals and caregivers. Additionally, Zenkoukai developed its own apps compatible with iPhone and iPad, actively participating in the development of smart long-term care technologies.

Zenkoukai's Care Robot Laboratory serves as an intermediary platform connecting care robot organizations, manufacturers, and R&D entities. It promotes three key activities: care robot development and verification, robot

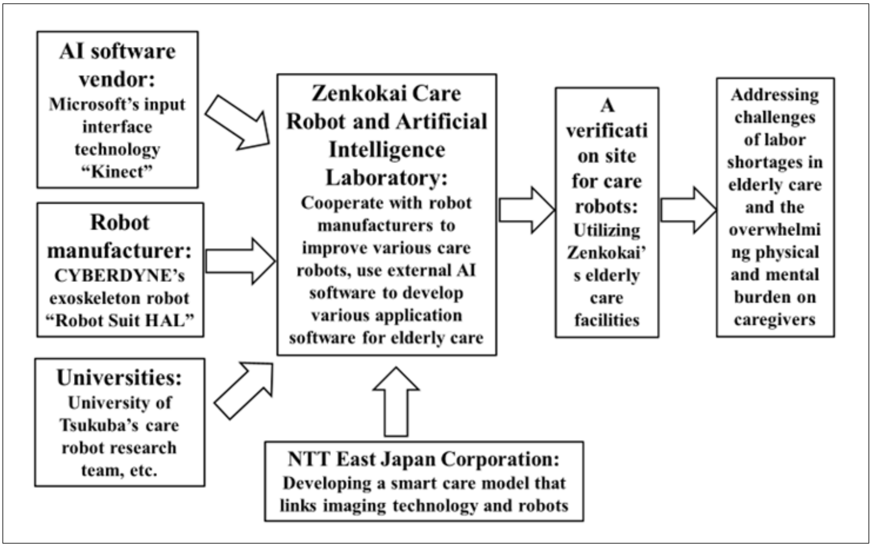
8 The author's interview with Director Takashi Miyamoto of Zenkokai, a social welfare corporation, on August 7, 2017, and referenced Nozomi Takeuchi (2024).

implementation, and government technology project support. In July 2016, the Care Robot Laboratory expanded to become the Care Robot and Artificial Intelligence Laboratory, focusing on integrating robotics with AI technology. The laboratory aims to reduce both caregiving and operational burdens while enhancing elderly care service quality.

Miyamoto emphasized that Japan’s elderly care service industry faces dual challenges: insufficient caregiving personnel and inadequate government subsidies. This forces care service providers to consider new service models that effectively utilize AI technology and care robots. Zenkoukai's Care Robot and Artificial Intelligence Laboratory promotes the Hybrid Special Nursing Home Project as its primary service model. This model integrates human caregivers with robotic assistance to deliver comprehensive care services. The model employs a bottom-up approach, selecting and testing robots based on elderly mobility needs and caregiving requirements. This process typically involves evaluating 30 to 40 robot types before final selection. The selected robots integrate with proprietary AI software to create a comprehensive care service system. For example, they developed a transfer training program using Microsoft Kinect’s skeletal recognition system. This program visualizes elderly walking patterns for fall prevention assessment and integrates with care robots to create a smart care system. This integrated system both effectively prevents falls during walking and helps caregivers understand the most efficient postures to assist the elderly.

Additionally, Zenkoukai and NTT East Japan conducted a verification activity for smart care leisure services linked with image technology and robots. The verification took place at Zenkoukai’s special nursing home, where communication robots transmitted television content for leisure activities, engaging both residents and caregivers. On-site caregivers reported that these smart services provided enriching content. They observed that robot interactions potentially slowed dementia progression while reducing caregiver workload. By 2024, Zenkokai’s affiliated elderly care facilities have introduced approximately 200 types of care robots into use.

Through collaborations with robot manufacturers, AI software companies, and ICT providers, Zenkoukai’s Care Robot and Artificial Intelligence Laboratory is fostering the development of a long-term care technology R&D network. This network addresses both the labor shortage in elderly care settings and the physical and mental burden on caregivers. (see Figure 4).



Source: Compiled from authors' interviews.

Figure 4. The R&D Network driven by Social Welfare Corporation Zenkoukai

3. Overview of Japan's Policies to Promote the Adoption and Application of Care Robots[9]

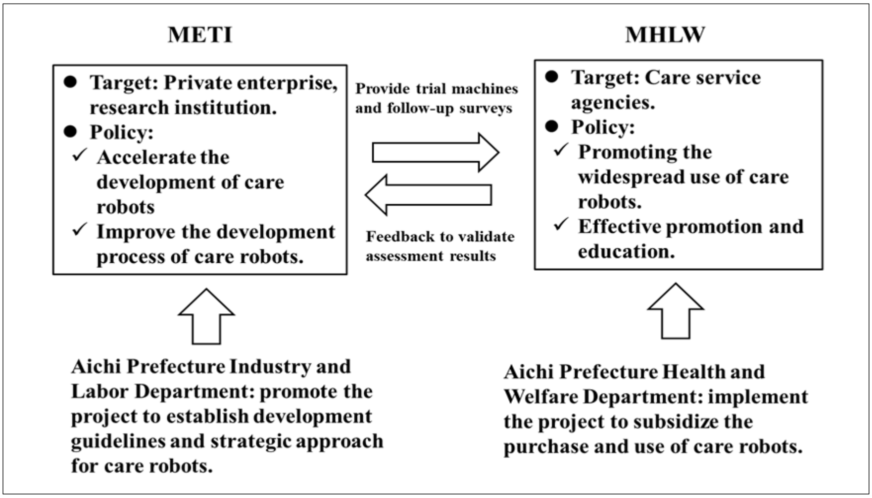
In recent years, the Japanese government has focused on advancing the industrial development of care robot technology. The main policy objective has been establishing a cross-agency collaborative mechanism between the Ministry of Economy, Trade, and Industry (METI) and the Ministry of Health, Labour, and Welfare (MHLW). This collaboration facilitates both technological development and real-world integration of care robots. METI subsidizes private enterprises and research institutions for basic and applied robot R&D. Meanwhile, MHLW subsidizes care assistive device organizations and universities to promote care robot adoption among service providers. MHLW also supports real-world care needs analysis and service validation. This includes gathering feedback on human-machine interfaces, enabling manufacturers to address implementation challenges promptly. Such support accelerates care robot adoption in both institutional and private settings. Following central government policy, local governments like Aichi Prefecture

9 The author's interview with the Aichi Prefecture Government on April 25, 2018, and referenced Aichi Prefecture (2024).

have actively promoted the industrial development of care robot technology from both user demand and R&D supply perspectives (see Figure 5).

At the demand-side policy level, the Aichi Prefecture Health and Welfare Department, through the Senior Welfare Section, has been implementing the Care Robot Introduction Support Project since 2016. The project subsidizes certified care service providers in Aichi Prefecture for care robot purchases under the long-term care insurance system. The types of subsidies are defined according to six functional categories outlined by the MHLW's Elderly Care Support Division, including: mobility assistance, transfer care, waste elimination, remote monitoring and therapeutic communication, bathing assistance, and general care assistance. Local senior care service providers must submit a care robot introduction plan for review. The Long-Term Care Insurance Advisory Committee evaluates these plans for needs alignment and category compliance. Subsidies are granted only upon plan approval. Providers must submit effectiveness and challenge reports after one year of implementation. These reports are then compiled and shared with other institutions and households considering robot adoption. The project granted subsidies to nine care service providers in its initial year (2016). Subsidy allocations increased annually from 2017 to 2022, demonstrating growing acceptance of care robots in private care services.

At the supply-side, the Aichi Prefecture Department of Industry and Labor promotes the Care Assistive Devices and Care Robot Verification and Evaluation Promotion Project. In alignment with METI's Care Robot Development and Adoption Promotion Program, this project establishes standardized verification mechanisms for smart assistive devices and care robots to accelerate commercialization. The project began by surveying Aichi's care service providers to assess their willingness to trial new robots and provide verification environments. Survey results showed strong provider interest in offering verification sites. This led to the next phase: establishing subsidy guidelines for care robot verification. Manufacturers and universities conducting care robot development and requiring verification were invited to apply. Finally, Aichi Prefecture established an expert committee comprising industry, academic, and research representatives. This committee reviewed applications and developed R&D guidelines for commercialization, providing reference standards for developers and institutions.



Source: Compiled from authors' interviews.

Figure 5. Japan's cross-departmental policy concept for promoting the development, popularization and application of care robots

V. Research Findings: The Concept of Demand-Integrated R&D Network

Based on the above case analysis, the importance of the demand-integrated R&D network becomes evident. Care robot development requires experiential communication with users at both physiological and psychological levels to create systems that meet actual needs. This approach facilitates the formation and growth of demand-integrated R&D networks. Recent research emphasizes the crucial role of future users in planning technological solutions. Their participation helps manufacturers design according to elderly needs and preferences (Sawik et al., 2023).

Robots, as semi-finished products, require system integration (SIers) with equipment and personnel to create production systems and service fields that meet industry needs. The convergence of robotics and AI has led manufacturers and system integrators to evolve into demand integrators (DIers) or service integrators, fostering problem-solving R&D networks. Nihon Unisys Company proposed the service integrator concept as a new business model.

According to Shirai (2012), director of Nihon Unisys's Talent Development Center, traditional system integrators (SIers) excel at hardware and software integration but can only satisfy customers' physical value demands. This limitation becomes more apparent with advancing technology and changing customer needs. However, this model cannot effectively meet service value demands, including talent development, management system construction, and value-added applications. Future system integrators must evolve into demand integrators, developing core capabilities in on-site improvement, technical expertise, and rapid service delivery to provide comprehensive solutions covering both intangible and physical value. This transformation enables long-term value co-creation partnerships with customers.

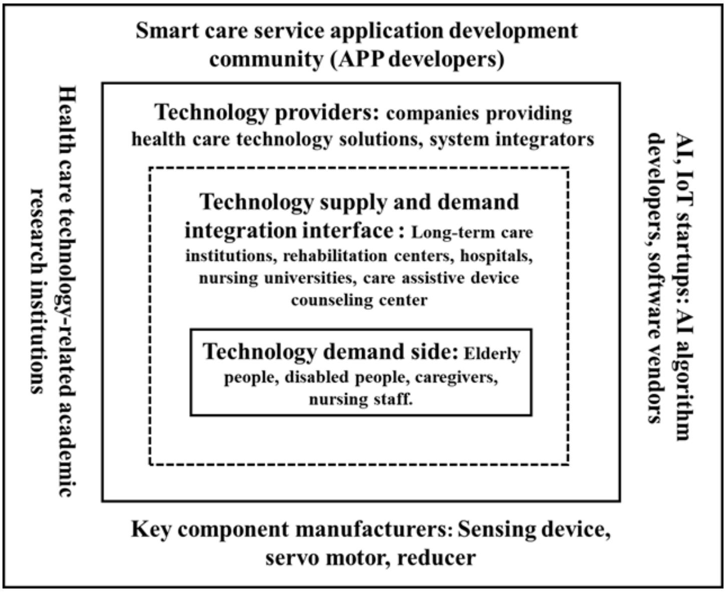
Care robots, as service robots, require connections with long-term care institutions, hospitals, rehabilitation centers, and households for effective R&D. Therefore, establishing a demand-integrated R&D network is crucial for care robot technology development

Effective care robot development requires holistic user engagement to ensure system relevance at both physiological and psychological levels, thereby fostering demand-integrated R&D networks.

VI. Conclusion and Recommendations

This study reviews the recent care robot developments in Taiwan and analyzes key issues in R&D network establishment. Drawing from Japan’s experience, it highlights the importance of demand integration in R&D networks to address Taiwan’s care robot development challenges. The demand-integrated R&D network strategy promotes user innovation and shifts academia-industry-government collaboration from technology supply toward addressing elderly needs, facilitating widespread application. This study proposes three strategic recommendations to promote Taiwan's care robot R&D networks.

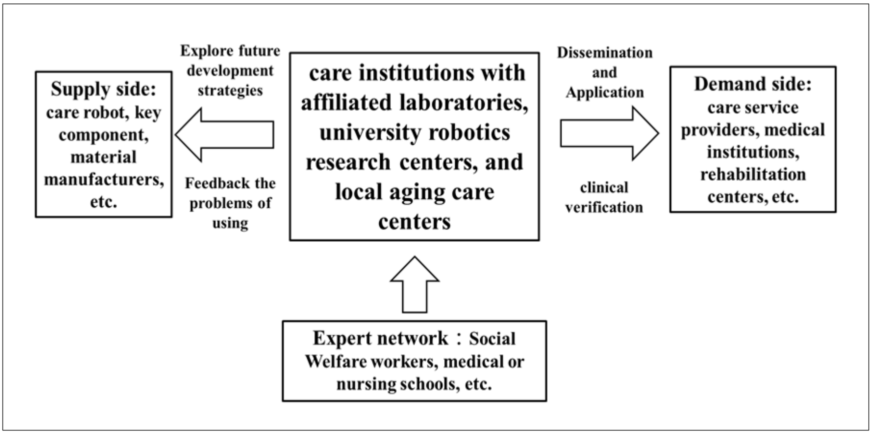
First, establish a demand-integrated business ecosystem centered on clinical co-creation. The R&D network should prioritize user needs—both elderly and care service personnel—to drive the development of key technology suppliers and system integrators. This will further guide the involvement of smart care service application development communities, AI and IoT startups, key component manufacturers for service robots, and advanced technology research centers related to care within academic and research institutions. Care robot service validation fields, established by various care institutions and universities, will serve as interfaces between technology demand and supply sides. This structure facilitates knowledge transfer and integration, fostering a clinical co-creation ecosystem among industry, academia, and research sectors (see Figure 6).



Source: Designed by authors.

Figure 6. Care robot drives a demand-integrated business ecosystem with clinical co-creation thinking

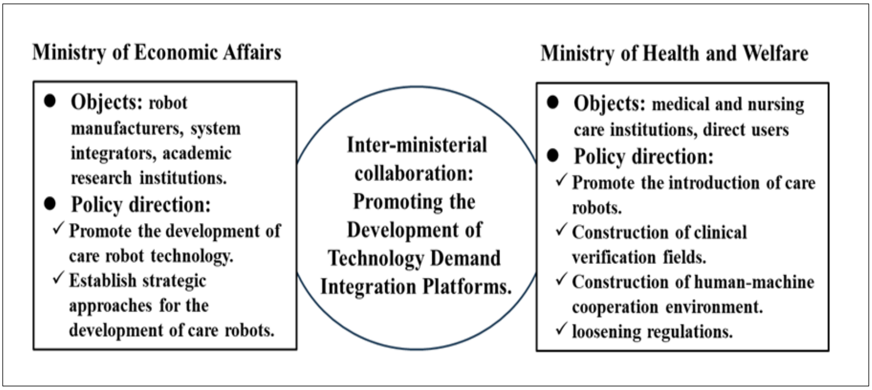
Second, establish a demand-integrated platform for care robot technology to address gaps in the development of key technologies and service validation. Taiwan's care robot R&D networks face two major challenges: inconsistent care robot service validation environments (clinical trial fields) and insufficient diversity in smart care service application development communities. To address these challenges, healthcare institutions, university research centers, and local aging care facilities should be encouraged to become co-creation platforms for care robot technology integration. This would promote the widespread establishment of robot validation and usage environments, foster expert networks in care technology, and provide clinical validation and professional consultation for care robot R&D (see Figure 7).



Source: Designed by the authors.

Figure 7. The concept of a demand-integrated platform for care robot technology

Third, accelerate care robot R&D and application through interdepartmental collaboration, supported by an integrated policy indicator system addressing super-aged society challenges. Successful care robot development and application requires close collaboration between R&D teams and end users. The Ministry of Economic Affairs (overseeing robot technology R&D) and the Ministry of Health and Welfare (managing care robot implementation) must establish effective interdepartmental collaboration to achieve policy goals. Furthermore, medical and care institutions have not yet widely established clinical validation and service experience facilities for care robots. Additionally, issues such as talent cultivation and regulatory adjustments require policy-level support and coordination. Figure 8 illustrates the essential need to clarify policy responsibilities between R&D and application domains while accelerating interdepartmental collaboration. An integrated policy indicator system must be developed to establish care robots as crucial tools for addressing super-aged society challenges.



Source: Designed by authors.

Figure 8. The inter-ministerial collaboration to promote the development and application of care robots

References

Aichi Prefecture, (2024). Care Robot Introduction Support Project. Retrieved from https://www.pref.aichi.jp/soshiki/korei/kaigorobotto.html

Board of Science and Technology, (2015). Research and industrial development of assistive technology. Executive Yuan.

FREE Bionics. (n.d.). Retrieved from http://robotcare.jp/.

Hsinchu Branch of National Taiwan University Hospital, (2024). "Kebbi" Robot Goes to Work! Hsinchu NTU Opens a New Chapter in Smart Healthcare. Retrieved from https://www.hch.gov.tw/?aid=71&pid=106&page_name=detail&iid=673.

Intelligent Home Robotics Research Committee, (2022). Regarding "HSR Development Community Call for Applications". Retrieved from https://www.i-homerobotics.org/hsr_community

Japan Agency for Medical Research and Development. (n.d.). Care Robot Portal Site. Retrieved from http://robotcare.jp/

Jocelyn, (2023). NimBO Muscle Strength Trainer. Retrieved from https://www.inside.com.tw/feature/robotics/30159-free-bionics-medical-robots-interview

Kobayashi, H., (2021). Occupational Support Technology and Maintaining Health through Posture Correction. Tokyo University of Science.

Toyota Motor Corporation, (2015). Life Support Robot HSR. Retrieved from https://newsroom.toyota.co.jp/jp/detail/8709536

Ministry of Health and Welfare, (2016). Ten-Year Care Plan 2.0 (2017-2026). Ministry of Health and Welfare.

Ministry of Health, Labour and Welfare, (2021). Healthy Life Expectancy in Reiwa Era. Ministry of Health, Labour and Welfare.

Ministry of Health, Labour and Welfare, (2023). Overview of the Simplified Life Table for Reiwa 4. Ministry of Health, Labour and Welfare.

Ministry of Health, Labour and Welfare Elderly Support Division, Ministry of Economy, Trade and Industry, Medical and Welfare Equipment Industry Office, (2024). Revision of Key Areas for the Use of Robot Technology in Care. Ministry of Health, Labour and Welfare, Ministry of Economy, Trade and Industry.

National Development Council, (2022). Population Projections for the Republic of China (2022-2070). National Development Council.

National Health Research Institutes, (2024). National Community Dementia Epidemiology Survey. Long-Term Care Department, Ministry of Health and Welfare.

Public Interest Incorporated Foundation Kanagawa Welfare Services Promotion Association. Retrieved from https://carerobot.kanafuku.jp/search/movie/

Sawik, B., Tobis, S., Baum, E., Suwalska, A., Kropińska, S., Stachnik, K., Pérez-Bernabeu, E., Cildoz, M., Agustin, A., & Wieczorowska-Tobis, K., (2023). Robots for elderly care: Review, multi-criteria optimization model, and qualitative case study. Healthcare, 11(9), 1-26.

Shirai, K., (2012). Establishing Sustainable Competitive Advantage through Service Integration. UNISYS Technology Review, (113), 43-57.

Takeuchi, N., (2024). Introduction and verification of over 200 types of care robots and tools! Zenko-kai's "digital care" initiatives. Retrieved from https://kaigoshoku.mynavi.jp/contents/kaigonomirailab/news/report/iv_2409_03/