A Roadmap of Information and Communication Technology-Oriented Product-Service Systems for Older Adults in Hong Kong

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***Abstract*—In light of the unprecedented growth of the aging population in Hong Kong, coupled with the massive diffusion of information and communication technology (ICT), the issue of the best approach to adopting ICT for solving aging problems has become a hot topic among stakeholders from industry, the academy, government, and elsewhere. Considering that older adults always exhibit a relatively low level of technology usage, product-service systems (PSS) could be an appropriate way of facilitating their acceptance of ICT. However, research on this topic is diverse and fragmented in conception and literature review. It is therefore necessary to conduct a systemic overview of the subject and propose a broader vision of PSS for ICT. This study reviews the recent progress of ICT for aging and its integration of pertinent product-service system as the basis for a roadmap which provides insights into future trends and challenges for the development of ICT-oriented PSS.**

Keywords—information and communication technology, product-service system, older adult, roadmap, gerontechnology

I. INTRODUCTION

The dramatic growth of the aging population in Hong Kong, ranked as the 7th fastest-growing elderly region, has posed a great challenge to the government, industry, academics, and all related stakeholders dedicated to promoting the soundness of the society [1]. Population aging has influenced Hong Kong in many ways, including healthcare system, living arrangements, labor market, pensions plan, social security system, and family structure. Information and communication technology (ICT), as one of the critical means of economic development and human social and communication links, could play a major role in coping with the social shifting associated with aging population.

Prior studies have acknowledged many advantages of ICT implemented for older people, including benefits in relation to social and self-understanding (e.g., access to news and health tracking), task-oriented goals (e.g., online shopping, e-financing, and takeaway services), and interaction benefits (e.g., increased connection with society) [2]. Although the importance and potential benefits of ICT for elderly people have been recognized, this group of people still exhibits lower levels of internet and electronic devices use compared with other groups of people [3], [4]. The recent outbreak of COVID-19 facilitates people's use of ICT due to the restrictions on direct social contact. People have to rely more on digital means to accomplish things and communicate with society. At the same time, this social change exposures barriers and problems with older adults' ICT usage. Nevertheless, it forces older adults to actively or passively learn technologies in order to address their living demands, such as contacting friends or relatives through video communication function. Some researchers indicate a vigorous increase in older adults' ICT usage in recent years. For instance, in Hong Kong, the internet usage for older people aged over 65 increased from 56.3% in 2018 to 62.2% in 2019, which was the highest growth rate among all age groups [5]. Nevertheless, the ICT adoption rates of elderly is unlikely to match the level of younger people. Consequently, research about ICT for older adults has become an important field of study.

Product-service systems (PSS), which integrate products, services, support networks and infrastructures into a system [6], could provide a leverage for ICT providers to increase older adults' acceptance of new technology. Many ICT providers recognized the advantages of applying PSS instead of providing solely either a product or a service for improving customer satisfaction and their competitiveness [7]. This is particularly true for those whose target customers including older people or whose products are specialized for the older customer. A key characteristic of PSS is its customized orientation [6], which is inherently better matched with the features of older adults, as they are more variable in dependency, ethnicity, wellbeing, physical condition, and financial status [8]. As a result, in the gerontechnology field, the PSS concept is more or less integrated into ICT products or services. For instants, MobileHelp is a medical alert system that integrated a simple used physical product with global positioning system (GPS) and commutation function and service of personal response for MobileHelp center to offering a final solution to ensure the well-being and safety of the elderly [9]. However, the current PSS for aging-related ICT spans fragmented and diverse spectrums of

research and practice. There is therefore a huge potential for the future development of ICT-oriented PSS, but the future trends remain uncertain.

This paper attempts to address these gaps, exploring PSS application in ICT for older people, in particularly how the social drivers, ICT-related technology and R&D affect its development. Roadmapping is employed as the research method in this study to provide the overview and vision of ICT-oriented PSS for older adults in Hong Kong. In contrast with the typical literature-based study that focuses on summarizing and synthesizing previous research [10], this study not only reviews the recent progress in ICT with PSS but also provides insight into future trends and challenges for the development of ICT-oriented PSS.

II. Methodology

A. Overview of Roadmap

As mentioned by R. Galvin [11], roadmapping is 'an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field'. This concept was first proposed by Motorola in the 1970s by providing a 10-year forecasting of its product and technology development, which synthesized the main elements of the company's strategic plan into a clear visual demonstration [12], [13]. Nowadays, the roadmap technique is widely used in various industries [14]-[22], and several roadmaps in the ICT field have been developed [22]-[25], but roadmap focused on technology for older adults is rare. In fact, there is no specific method for roadmap development, and the approach has been adapted to support various purposes, with differing scopes and levels of generality [26].

In this study, the idea of technology roadmapping is applied with the aim of capturing the current progress, future trends and challenges of ICT-oriented PSS development for the aging population. Technology roadmapping enables exploration of the future trends of product/service/technology/tool with dynamic linkages between changing environment, industrial direction, and technological resources [12], [22]-[24], [27]. The technology roadmap approach can be regarded as extracting key themes from the strategic change and strategic technology planning literature, by combining a layered structure with the time dimension [12]. The most commonly used technology roadmap developed by European Industrial Research Management Association (EIRMA) is shown in Fig. 1 [28].

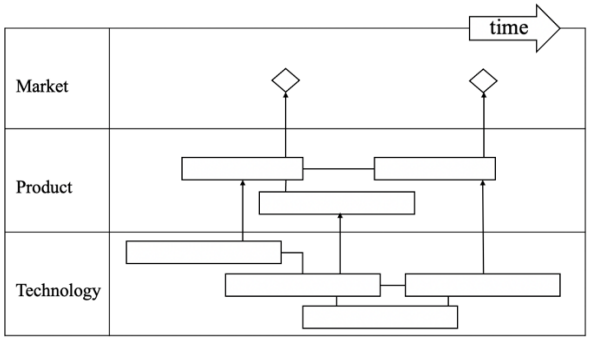

Fig. 1. A common structure for technology roadmap (Adapted from [28])

B. Research Process

As forecasting the future and investigating the interdependencies among all driving forces associated with a targeted field is difficult in nature, a profound roadmap requires comprehensive consideration of a variety of factors from different resources in the field. In order to appropriately integrate the various contributions into the right context, it is necessary to follow a systematic process [29]. In fact, there is no commonly used procedures for building a technology roadmap. However, by comparing and contrasting various studies of technology roadmap development [22]-[30], this study has identified the following three phases, combining six steps, as shown in Fig. 2. The first phase is to generate the basic idea of the research. After the goals of the study were established, the basic research has been done to define the roadmap structure (i.e., technology roadmap) and the main themes to be investigated have been set (i.e., aging problems in Hong Kong, social need and drivers, ICT in aging, PSS in ICT, and ICT technology and resource). Along with the main themes, the key stakeholders who play critical roles in determining the direction of future development need to be identified [22]. In this study, older adults, government, industry, the academy, and caregivers are identified as the key stakeholders that influence ICT-oriented PSS development for the elderly.

As a result, data were collected using online desktop research techniques based on the main identified themes from the perspectives of these five key stakeholder groups in the second phase. To obtain inclusive understanding, multiple types of data-sources were collected, including research papers, conference proceedings, government reports, government websites, industrial reports, business websites, surveys, and news media. Based on these research materials, the future trends were captured and articulated through vision, scenario, and challenge analysis. In the third phase, a roadmap was drawn based on the results identified by the data analysis.

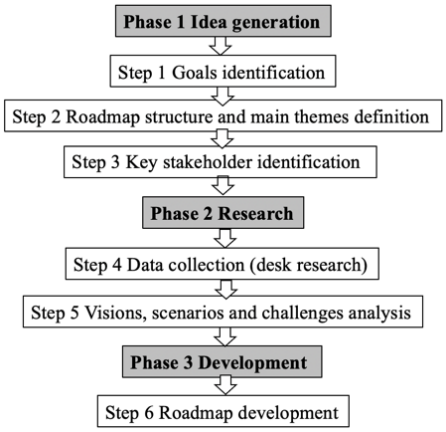

Fig. 2. Research methodology and process

III. Results

A. Social Needs and Drivers

- Aging in Hong Kong

According to the latest statistics by the Hong Kong Census and Statistics Department, the number of Hong Kong citizens aged above 65 years old reached 1.32 million in 2019,

accounting for 18.4% of the total population [31]. The World Health Organization (WHO) defines a society as an 'aging society' when the proportion of the population aged over 65 exceeds 7% of the total population; and when the proportion of people aged over 65 exceed 20%, it is regarded as a 'super-aged society' [32]. The data indicates that Hong Kong's transition to the 'super-aged society' is imminent. The growth rate of the elderly population will increase at a much faster pace in the coming decades and it is projected the percentage of the population comprised of the elderly will increase to 26.0% by 2029 [31].

With the ascending older population, the most direct impact will be the rise of the old-age dependency ratio, which means that there will be an increased strain on those in the labor force to support those who are economically dependent [33]. Associated with this change, the number of care institutions will increase to cope with the increasing number of elderly people, thereby leading to increased demand for caregivers. However, it is difficult to retain more caregivers due to the shortage of labor force in the market and this shortage of caregivers might become serious from the 2030s onwards [31]. On the other hand, with technology development and accumulated medical experience, Hong Kong enjoys the longest life expectancy in the world, which was 82.2 years old for males and 88.1 years old for females in 2019 [34].

- Older Adults Needs

As society evolves, older adults' needs and demands will change accordingly. The increasing dependency ratio leads to a change in living arrangements. According to the United Nations, in the developed regions, the proportion of older adults living with only a spouse is the most common living arrangement and living alone ranked second, while living with an extended family is becoming less common [35]. Along with it, there is a phenomenon of 'aging in place', where the older people are more willing to stay at their home instead of living in the nursing house in their retired life due to the feeling of comfort and convenience when living in a familiar environment. Some gerontologists found that in the current stage, the majority of the older population is able-bodied, if they have the opportunity to live actively and independently, they are able to generate more value to our society, such as their knowledge and experience [36]. Researchers further indicate that, during the next decade, the new generation of older people will have a better financial and education level. As a result, they are more likely to have higher demands of life quality [37].

- Government Drivers

As a key stakeholder, the government plays a critical role to strategically channel ICT-oriented PSS development for the elderly. Recognizing the severity of the aging problem in Hong Kong, the government has conducted a variety of thematic research initiatives to understand the condition of older people. From the thematic household report on personal computer and internet penetration, the low-level usage of computer and internet for older people is acknowledged [5]. As a result, the Hong Kong government has been endeavoring to implement varied initiatives to facilitate wider adoption of ICT for older people over the years. From 2012 to 2020, the government launched a series of ICT programmes for the elderly, for enhancing the elderly adoption of ICT and enlarging their social circles. As shown in Table I, it is found that the activities, technologies, and range and volume of participants in the programme have expanded and evolved year by year [38].

TABLE I. ICT PROGRAMMES FOR THE ELDERLY

Year	Contents	Participants
2012-2013	Established supporting projects to enhance elderly access, knowledge, skills and receptiveness on the use of ICT, mainly for computer and mobile phone, with the perceptive of improving their life quality and broadening their social circle.	Around 4000 elderly persons
2013-2014	Outreach programmes for hidden elderly to arouse their awareness and improve their interest of ICT	38 elderly homes, and over 1000 elderly persons
2015-2016	Second round outreach programmes that extended the service scope to cover elderly receiving day care services and home care services	63 residential care homes and day care centers and over 2000 elderly persons
2017-2018	Third round of the programmes that extended to elderly with dementia with the view of helping them through the aid of digital technology	2500 elders, and over 100 residential care homes and day care centers
2018-2020	Two years programme that launched new enriched ICT training programme for elderly to provide advanced training to enhance their capability of digital technology usage in daily life	11 elderly academies

To create a favorable environment for gerontechnology development, the Hong Kong government has established certain measures. In 2018, the government launched a HK$ 1 billion 'Innovation and Technology Fund for Application in Elderly and Rehabilitation Care' to subsidize elderly service organizations to purchase, rent, and trial use of gerontechnology products and services [39].

Moreover, the government progressively increases the public expenditure on the elderly. In 2020, the expenditure on the elderly reached HK$ 91.9 billion (20.8% of total public expenditure) with an average growth rate of 11.4% [40]. In addition to financial input, the government dedicates to create opportunities for industry practitioners and professionals to exchange knowledge and share their innovative gerontechnology, such as the 'Gerontech and Innovation Expo cum Summit' since 2017 and 'GeronTech Cluster' launched in 2019 [41], [42]. From the legal aspect, the issue of some outdated regulatory systems and policies toward gerontechnology have been posted in the recent legislative assembly and the government promised to improve the current systems through collaboration among all related departments [43].

B. ICT-oriented PSS

There are numerous examples of research investigating older adults' acceptance of ICT in which the focus has mostly been on older peoples' usage of computers, the Internet, and mobile phones. In fact, however, ICT has a much wider application in gerontechnology. Ivankina et al. [44] identified four areas of ICT application for older people's daily life, namely, finance, administrative activity, communication and leisure, and methods of technology adoption. Besides these, ICT can also be adopted in other gerontechnology domains, such as healthcare. Bouma, Fozard and van Bronswijk [45] distinguished five domains of gerontechnology: housing and daily living, communication and governance, health and self-esteem, work and leisure, and mobility and transport. By integrating these two classification schemas, this study adopted a three-category

classification system for ICT for older adults: communication and leisure, healthcare, and housing and daily living. In each application area, one typical application is demonstrated to elaborate on the progress and future trends of its associated PSS development.

- Communication and Leisure

The senior phone is one of the most successful products adopted by older people for communication. Some years ago, many older people preferred to use the mobile phone without smart functions, especially the oldest old, due to the complexity of smartphone operation. Maguire and Osman [46] found that, at that time, older adults' primary need on the mobile phone was to obtain assistance in emergencies. Nowadays, the landscape has changed, and more and more activities need to be accomplished through the smartphone. In addition to the safety motivation, older people also regard the mobile phone as social interaction and task-organization tool [47]. As a result, some gerontechnology producers are currently developing senior specialized smartphones, which add some basic smart functions to the senior phone. However, this kind of smartphone lacks functionality compared with the normal smartphone. On the other hand, most normal smartphones do not address the distinctive needs of older users in their original design. As a result, the difficulty for older people in using smartphones has increased. To successfully capture the knowledge of smartphone use, most of them need assistance from others. This situation has raised concern by both government and non-governmental organizations (NGOs), which leading them to publish some trainings and courses to facilitate older adults' use of smartphone, such as the aforementioned 'ICT programmes for the elderly' by the Hong Kong government. Recognizing these progresses, some smartphone providers, such as Apple Inc., have launched tutorials to teach their customers how to use their product [48]. To improve usability, some elder-friendly features have been added to the smartphone through the upgrade of software, such as adjustable text size, text-to-speech conversion, audio descriptions, and voice control [49]. Many producers are engaged in the development of customized systems for the elderly that will possibly be launched during the next few years.

- Healthcare

Telecare comprises a mixture of computing, telecommunications, and information technology to support older people's health protection at a distance. It may provide health services to the end-user directly through remote systems. This kind of service has been available in some western countries for more than 20 years, and it has also been applied in Hong Kong for more than 10 years. The first generation of this type of system consisted of a device with wireless remote triggers. When the user pressed the trigger, the system would automatically contact the administrator or help center.

With the development of smart technology, the system has further evolved. Facilitated by the popularization of broadband communications and networks, and the advancement of sensor technology, the current second-generation systems is able to collect the user's life information and monitor and measure the user's body condition by itself. Now, its functions include not only the emergency contact and alert, but also the measurement of physiological functions, medicine reminders, and the detection of unusual situations. The third generation of telecare systems would involve the support of medical personnel and realize the intelligent monitor. In the current outbreak of COVID-19, some advanced telecare systems have commercialized this function and will be diffused further during the next few years. In the foreseeable future, the fourth-generation telecare will integrate audio-visual technology to enable virtual consultation from healthcare personnel, hence reducing the need for doctors' home visits and older people' s hospital visits. In this way, older people would feel more empowered in their life [50].

- Housing and Daily Living

Companion robots are designed for the purpose of accompanying and assisting older adults to live active, independent and engaged lives. One type of companion robot associated with ICT is the intelligent speaker for the elderly. Its voice interaction function allows older adults to communicate with the robot and control the system through voice. Older people may use it to carry out various activities, including daily life management, accessing social media, playing music and video, and health management. From the service perceptive, as intelligent-speaker providers have a sufficient ability to create a smart product, they always integrate the smart feature into their service as well, such as intelligent customer service. The recently developed companion robot, ElliQ, further improved the 'intelligence' of the system. Through machine learning and computer vision, it can provide proactive suggestions to older adults in their daily life. These suggestions are personalized according to the previous experience, records, and preferences from the user, which is considered as individualization of services [51]. It also allows caregivers to pre-set some goals and the robot can automatically make a decision based on the context. The product is currently in the internal testing phase and will launch to the market soon.

In the next stage, the intelligent speaker might focus on integrating voice technology with other products. Although from the technology aspect, the current product is able to realize the voice control of other home electronic devices through system integration. The present devices in most elderly's home lacks smart functionality to integrate with intelligent speakers. It takes time to achieve a full connection, and when it accomplishes, the convenience of older people at home could be highly improved. Moreover, the voice assistants will continue to offer more customized experiences with more human-like interaction in order to provide a more real feeling to older adults of being accompanied. At that time, many intelligent speaker providers will formulate the smart PSS [52].

C. Technology and Research Development

ICT technology is an ever-changing field and those who want to remain at the helm of innovation must be aware of the latest trends. Information network infrastructure is the foundation upon which all other advanced technologies and functions in this domain will be based. The years 2020 to 2021 are the period during which network upgrading from 4G to 5G will take place. The commercialization of 5G will usher users into a new era of improved network experiences. The Chinese government is currently dedicated to constructing information network infrastructure and it believes the 'digital divide' among

older adults will be narrowed through the popularization of 5G [53]. During the next decade, 6G technology might be launched, which would integrate satellite signals with user systems on the ground. Along with network technology, big data has also achieved advancement in technology use for the aging. It evolves from basic big data analysis to tracking and analyzing all possible user behaviors, which largely supports the health monitor product. Another widely applied technology is artificial intelligence (AI). Its integration into gerontechnology is expected to be predictive, personalized, preventive, and participatory, which could bring disruption of current care processes and relationships. Virtual reality (VR) will also become prevalent and as mentioned in the previous section, some aspects of the medical profession are projected to rely upon VR for interaction and some treatments with older adults in the coming years. On the other hand, the growing use of these technologies may leave a high amount of personal data at risk of breaches. As a result, the product and service providers need to address cybersecurity and privacy issues and find a practical solution to the envisaged problems.

From the research perspective, many studies of older people's perception of ICT and factors that influence older adults' ICT acceptance has been conducted. Although variations exist across the studies, usability, affordability, accessibility, value, emotion, independence, experience, confidence, technical support, and social support are the factors commonly agreed upon by researchers as being the most salient [43]. After identifying the older adults' adoption condition (what) and the reasons behind their low ICT acceptance (why), researchers will increasingly focus on the problems associated with 'how' in the next stage. More research on the methods, approaches and applications for the development of ICT and its related PSS will be conducted. At that stage, issues related to the ethical implications of ICT for older people need to be considered, and researchers have a responsibility to facilitate the industry's practical implementation of ethical principles [54].

IV. Challenges

After analyzing the current status and future trends on social change and older adults needs, ICT-oriented PSS evaluation, and ICT technology and research progress, three key challenges have been identified that may be encountered in the process of ICT-oriented PSS development.

A. Elderly People's Lower Acceptance Level of ICT

Elderly people are considered to be a later adopter of technology, as they always tend to favor the product with which they are familiar and resist new technology. Despite the increased adoption of the Internet, computers, and smartphones, older adults still exhibit a lower level of ICT usage. Lots of factors have been identified that potentially influence older peoples' ICT acceptance, as listed in the previous section. The implementation of PSS can help to moderate some barriers to the adoption of technology by elderly people. For instance, technology support can be accomplished through integrated services provided by the manufacturer, and the affordability problem may also be alleviated as PSS has the ability to reduce the product cost by providing alternative scenarios for the use of product, such as rental and sharing schemes [6]. However, how to adopt the PSS and applying which kind of PSS is still a challenge for the ICT providers. If they fail to integrate an appropriate PSS, it might even be counterproductive to acceptance by older adults.

B. Lack of Collaboration Among Different Stakeholders

ICT for older adults can be considered as one type of gerontechnology. Given its natural interdisciplinary attribute, there is a necessity for cross-sectoral collaboration from different stakeholders to promote the development of the PSS application in ICT gerontechnology. The report from 'Our Hong Kong Foundation' indicates that Hong Kong is insufficient in collaboration within the gerontechnology ecosystem among different stakeholders, which, as a consequence, obstructs the advancement of ICT products and services [55]. Each sector and stakeholder has its role and advantage in the research, development, testing, commercialization, and enhancement of ICT-oriented PSS. For instance, the technology produced by business sometimes needs helps from NGO sectors to accomplish some service functions, as they have a tighter relationship with the end-user. Although evidence exists for collaborative efforts in Hong Kong, such as the collaboration between research institute and university, compared with the world-leading regions on gerontechnology, such as America and Japan, the dialogues and partnerships are far from sufficient.

C. Outdated Regulatory Systems and Principles

The technologies and their PSS designed for older adults are different from other groups of people, as older people are physically and cognitively different from younger adults, and more stakeholders are involved in this process. As a result, the current regulatory systems in Hong Kong lack the effectiveness to guide the implementation of ICT-oriented PSS for the elderly. More sophisticated regulatory frameworks and policies for gerontechnology are needed to direct the design, production, configuration, commercialization, and use of ICT-oriented PSS. The regulatory departments should collaborate with relevant stakeholders to provide a solid approach to support the rights of older people, especially focus on the ethical issue generated from the development and use of ICT-oriented PSS. Simultaneously, policies and regulatory frameworks that recognize, promote, encourage, and support the involvement and continuing contribution of elderly people to society is another critical issue that needs to be considered [56].

V. Roadmap of ICT-oriented PSS for Older Adults in Hong Kong

Based on the results of the previous sections, a roadmap of ICT-oriented PSS for older adults developed here is shown in Fig. 3. In order to assess the likely timescales of ICT evolution, several studies of the technology roadmap for the ICT industry [24]-[26], [30], [57] have been consulted. Four sub-periods have been identified, namely: 'past', representing PSS and technology viable within the past 5 years (2016-2020); 'short-term', representing a window of current 1-2 years (2021-2022; 'medium', representing the next 2-5 years (2023-2025); and, 'long-term', representing the next 5-10 years or beyond (2025-2030). This roadmap comprehensively demonstrates the progress and trends of ICT-oriented PSS in silver market through mapping out the social needs and drivers, ICT product, service and its functionality, and technology and research advancement.

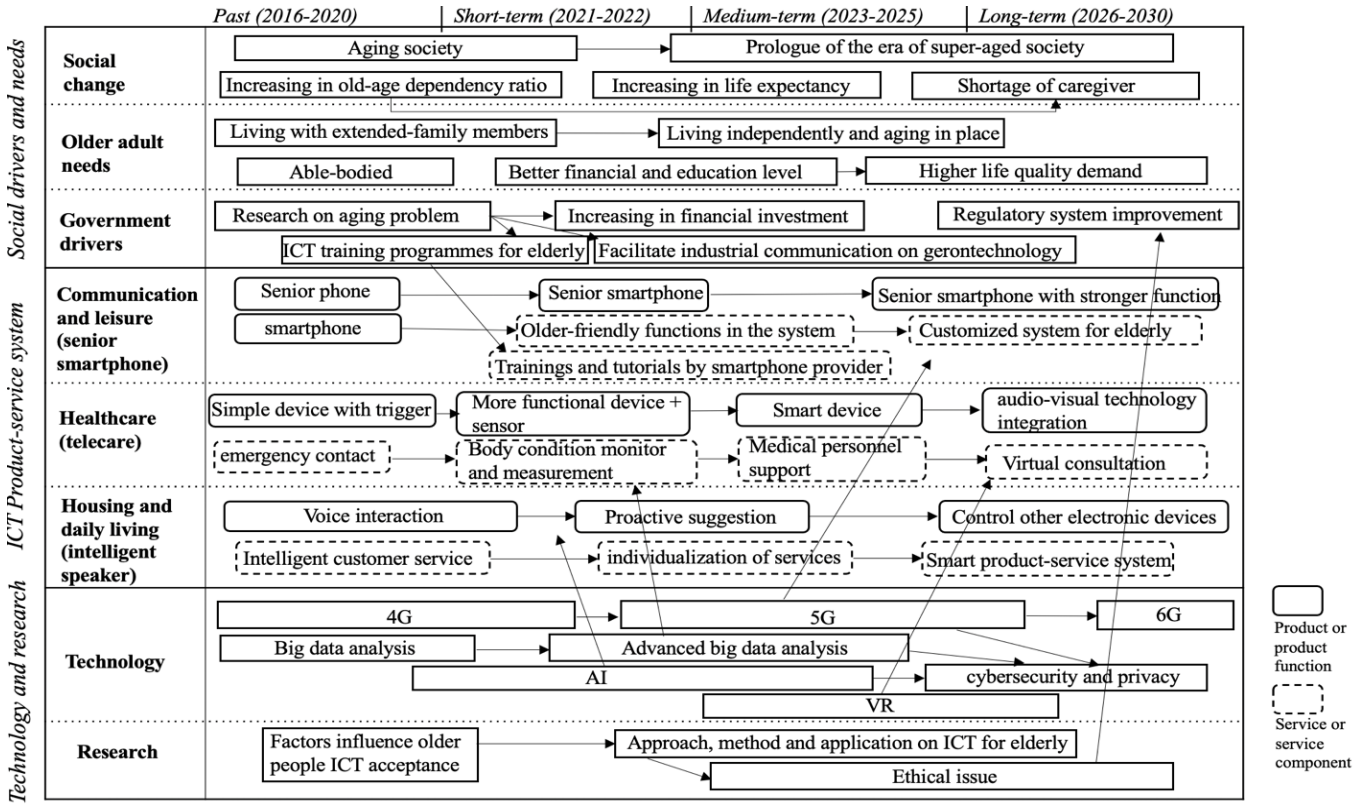

Fig. 3. The roadmap of ICT-oriented PSS for older adults

VI. Conclusions

This paper presents a roadmap for the future development of ICT-oriented PSS for aging, which is developed through the data collection, analysis, and demonstration of various types of research materials. It discusses the course of development of products and services of ICT for the elderly, accompanied with social divers and needs and the progress on ICT technology and research, by allocating the period 2016 to 2030 into four sub-stages, which are the past (2016-2020), the short-term (2021-2022), the medium-term (2023-2025), and the long-term (2026-2030).

This roadmap provides an important means to support manufacturers to gain a better understanding of the social drivers, needs, and expectations of the elderly and the progress on technology and research development in the ICT domain, which enables them to develop better gerontechnology products and services for satisfying the need of elderly people.

From the researcher's perceptive, in addition to the review of the previous research outcomes and current progress on ICT-oriented PSS, the future perspectives proposed in this study may provide some insights to inspire researchers in their future research work and the method for developing roadmap can be used into other domains. Despite the contributions, there are some suggestions for further study. For example, some inputs can be solicited through collecting feedback and comments from the subject matter experts and stakeholders. This will be helpful for validating the roadmap.

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