AGEING IN JAPAN. DOMESTIC HEALTHCARE TECHNOLOGIES.

A Qualitative Interview Study on Care Robots, Monitoring Sensor Systems, and ICT-based Telehealth Systems.

Report. May 2018.

Susanne Brucksch

Franziska Schultz

Deutsches Institut für Japanstudien
German Institute for Japanese Studies Tokyo (DIJ)
ドイツ日本研究所

Contact:
Dr. Susanne Brucksch (DIJ), Project Leader
brucksch@dijtokyo.org

ドイツ日本研究所
Deutsches Institut für Japanstudien
German Institute for Japanese Studies (DIJ)
7-1 Kioicho
Jochi Kioizaka Bldg. 2F
Chiyoda-ku, Tokyo 102 0094
Tel: +81 3 3222 5077
Fax: + 81 3 3222 5420
www.dijtokyo.org

Ageing in Japan.

Domestic Healthcare Technologies.

A Qualitative Interview Study on
Care Robots, Monitoring Sensor Systems,
and ICT-based Telehealth Systems.

Report

Susanne Brucksch

Franziska Schultz

Tokyo, May 2018

Preface and Acknowledgement

This report presents findings of a joint research project between the Leiden Asia Centre and the German Institute for Japanese Studies (DIJ). The project was initiated and financially supported by Leiden Asia Centre under their research scheme “Aging Japan: Leading the way into the future”.

The project on “Ageing in Japan: Domestic Healthcare Technologies in Japan” was conceptualised and conducted at the German Institute for Japanese Studies (DIJ). DIJ also prepared this report, partially under its research scheme of “The Future of Local Communities in Japan. Risks and Opportunities in the Face of Multiple Challenges”.

We are particularly grateful for the valuable comments on an earlier version of the manuscript by Professor Kasia Cwiertka, Professor Franz Waldenberger and Dr. Barbara Holthus. Our grateful thanks are extended to Dr. Michel H.C. Bleijlevens, Dr. Kazue Haga, Ms Rie Masuda, Ms Junko Sakurai, Ms Miki Akaike, Ms Josine Schouwstra and Ms Anne-Sophie König for giving advice or providing research assistance at various stages of the project. We also wish to acknowledge the great administrative support offered by Ms Elisabeth Jakubassa.

We would like to express our great appreciation to the following institutions and organisations for their assistance with the collection of our data or for allowing us to visit their workplaces or laboratories: Robot Safety Center, Mobilika, Panasonic Age Free, Sekisui House, Fukui Prefecture, Iida City and all the interlocutors, who shared their valuable expertise and knowledge, which greatly enhanced the research.

Contents

1 Introduction

Japan is confronting a fast ageing population. In 2015, 26 percent of the population were aged 65 years or older. The share is expected to rise to 30 percent in 2025 (CaO 2017). Ageing implies increasing public expenditures on long-term care. Between 2000 and 2016, Japan's public contributions to long-term care insurance tripled. They are expected to double again by 2025 (MHLW 2015c: 12, 38). Japan is facing these challenges in the context of an extremely weak fiscal condition. In addition, lack of healthcare professionals and nursing staff for the elderly has become a severe problem. This holds especially true for regions outside of the large agglomerations.

The Japanese government defined a number of policy priorities to cope with these pressing issues. These include measures that contribute to the prolongation of healthy life to reduce the dependence of the elderly population on long-term care and to enable elderly and other people with disabilities, long-term illnesses or physical conditions to continue living at home. The overarching goal is the reduction of costs.

Government support of domestic care technologies represents a central pillar among these efforts. It is expected that technological advances and innovation in the field of domestic care will not only help the elderly, but will also reduce the financial burden of medical and long-term care and alleviate the shortage of care professionals by

- allowing for more long-term care at home,
- reducing the number of nursing and caregiving staff needed to provide long-term care,
- improving the working conditions of care workers by alleviating the physical strains involved with long-term care,
- thus, making it easier to attract new care workers.

The present study explores emerging domestic healthcare technologies in Japan. Based on secondary sources, the next chapter describes the demographic and related challenges in more detail, outlines respective government policies and gives an overview of the country's long-term care insurance (LTCI) scheme and the domestic care technologies covered by the system at present. Chapter 3 then presents the results of case studies that examined the development and use of high-tech solutions including ICT-based telehealth systems, monitoring sensor systems and care robots. Two case studies specifically looked at implementations in peripheral regions, where ageing and labour shortages are most severe.

The research was guided by the following questions:

- **Material Dimension:** *What kind of domestic healthcare technologies can be found in Japan? What stage of development or implementation can be observed?*
- **Social Dimension:** *What added value do domestic healthcare technologies generate from the perspective of users and developers?*
- **Financial and Regulatory Dimension:** *What financial and regulatory requirements do domestic healthcare technologies face?*

We therefore not only looked at the technical viability of specific solutions (material dimension), but also considered developer motivation and user acceptance (social dimension) and economic viability as well as compliance with safety requirements (financial and regulatory dimension). By moving beyond the technical characteristics, we were able to take into account the embeddedness of technology in specific social, economic and regulatory environments and to assess the actual practicality of solutions.

The research project "Ageing in Japan: Domestic Healthcare Technologies" was launched, because the speed and intensity of Japan's demographic change, the innovative capacities of Japanese companies and the political priorities set by the Japanese government make Japan a leading case for exploring emerging solutions of domestic care technologies. Given the limited time and financial resources available, we can only offer partial and preliminary results, leaving important aspects to be answered by future research. We nevertheless expect the results of our study to be of relevance beyond the case of Japan, as many European governments are evaluating the potential of domestic healthcare technologies in the context of rapidly ageing populations.

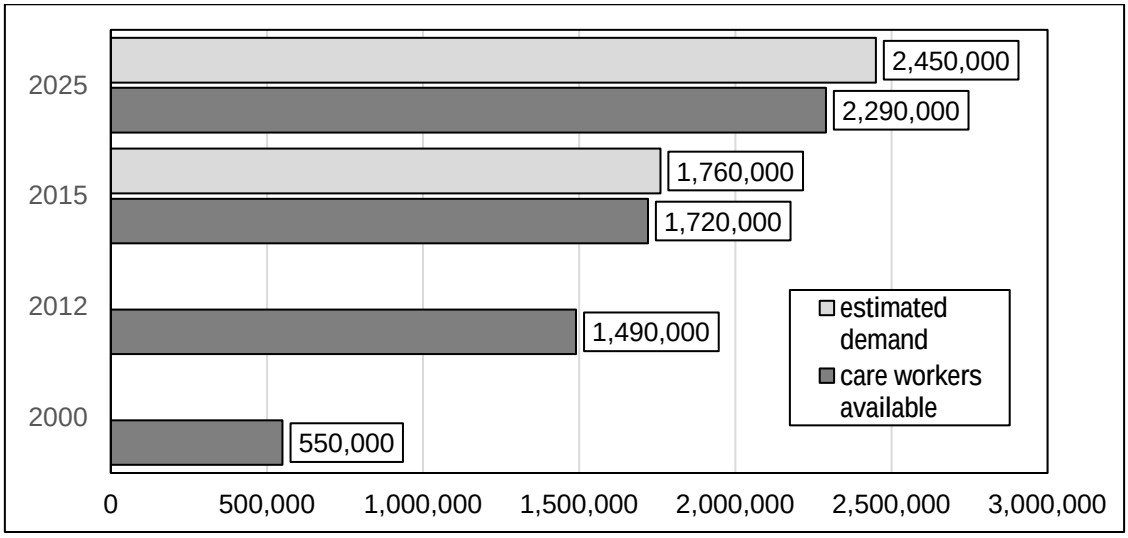
2 General Situation of Ageing and Long-Term Care

In this chapter, we will describe in more detail (a) the demographic challenges Japan faces with regard to long-term care and (b) the institutional framework provided by the public insurance system and by national as well as prefectural and local policies. This background information is needed to understand the context, which defines the needs and financial and regulatory constraints for the development and application of domestic care technologies.

2.1 Japan's demographic challenge

In 2016, about one-quarter of Japanese people were aged 65 and over. According to medium estimates, about 30 per cent of the Japanese population will be 65 or older in 2025 (CaO 2017). More precisely, there will be about 15 million people between 65 and 74 years of age and 22 million people aged 75 or over. Statistically 5.8 people aged between 20 and 64 supported one person over 65 in 1990, the figure was 2.2 in 2016. In 2025, barely 1.9 people on average will carry the financial burden for one elderly person. In 2060, one elderly person is expected to be supported by just 1.4 people of working age in 2060 (CaO 2017). Giving the rising number of elderly people in need of care, the demand for professional caregivers is expected to rise in Japan (see Figure 2.1).

Figure 2.1: Number of professional workers in long-term care in Japan

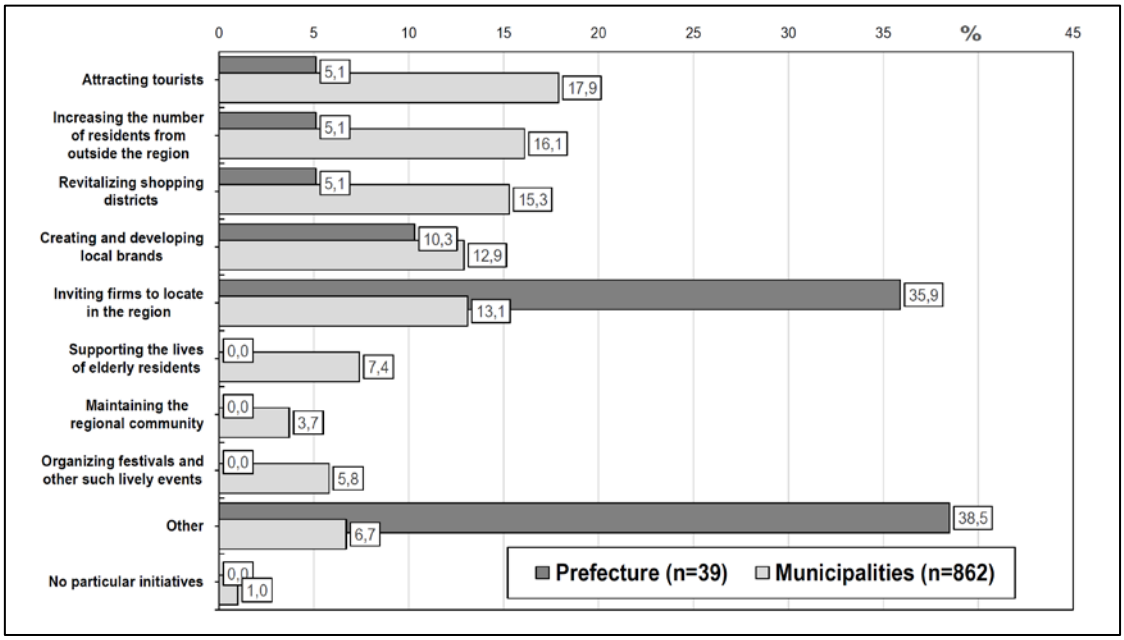


Source: MHLW 2014a, p. 15.

As shown in Figure 2.1 above, the number of long-term-care professionals increased from 550,000 in 2000 to almost 1.5 million in 2012 (MHLW 2014a: 15). The Ministry of Health, Labour and Welfare (MHLW) estimates that the number will further rise to 2.29 million in 2025. In comparison, the MHLW anticipated the need for 2.45 million long-term-care professionals in the very same year, which would imply a shortage of 160,000 people. However, in its latest update in 2015, the MHLW estimated the demand for professional care workers in 2025 to be 2.53 million and the actual supply at 2.15 million, implying a gap of 380,000 care workers (MHLW 2015a: 15).

Ageing and labour shortages are most severe in peripheral regions (Zenshukyo 2015, see also Matanle and Rausch 2011)[1]. In 2010, 29.6% of the population in Akita (Northern Honshū) was aged 65 and over, followed by 29.1% in Shimane (Western Honshū) and 28.8% in Kōchi (Shikoku) (SME Agency 2014: 100). An ageing society passes through two phases: in the initial phase, the proportion and number of elderly people increases. During the latter phase, the overall population declines. In those communities in Japan with the highest proportions of elderly, such as the municipalities of Kosaka, Kamikaori and Fujisato in Akita Prefecture in Northern Honshū, the latter phase of demographic change has already started. Moreover, emigration from these communities accelerates the process of shrinking and its social and economic consequences (SME Agency 2014: 96, 104). The vicious cycle of ageing, shortages of care workers, declining tax revenues and growing public expenditures puts extreme pressure on these municipalities.

Figure 2.2: Frequency of measures taken by prefectural and local governments[2]



Source: SME Agency 2014, p. 93.

[1] Peter Matanle and Anthony S. Rausch provide with their anthology *Japan's Shrinking Regions in the 21st Century: Contemporary Responses to Depopulation and Socioeconomic Decline* (2011) a broad overview of the various challenges faced by shrinking regions throughout Japan and their responses.

[2] *Note*: (1) The above figure shows priority measures that were selected as the most important measure taken in response to issues in local communities, from among each respondent's top

Figure 2.2 shows the various kinds of measures taken by prefectural and local governments to fight these trends. The priority of municipalities is to revive the regional economy and to invite firms to locate in their regions (35.9%). In contrast, the goal of ensuring a decent life for elderly residents ranks low for local governments (7.4%) or is non-existent for prefectural governments (0.0%). Although Japanese communities have made various efforts to improve the quality of life for their residents, these projects are not primarily targeted at elderly and frail residents (SME Agency 2014: 93). Most local governments seem to hope that improving the economic conditions will turn the vicious cycle into a virtuous one and thus indirectly improve the provision of care and a decent life for the elderly population.

2.2 Care Policies and Living Situation at the End of Life in Japan

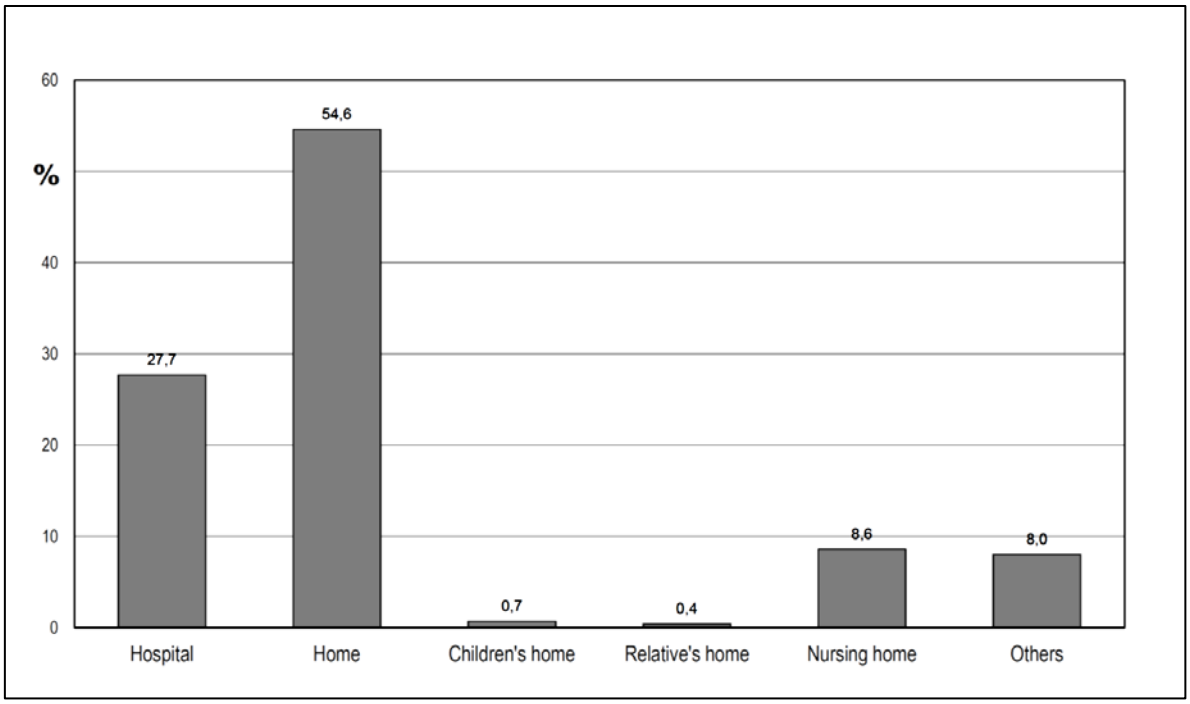
In Japan, public expenditures for LTCI soared from 3.6 million yen in 2000 up to 10.4 trillion yen in 2016. According to recent estimates, expenditures are expected to reach 21.0 trillion yen in 2025 (MHLW 2015c: 12, 38). It is obvious, that many measures undertaken by the government and local communities focus on cost reduction. Health maintenance programmes are seen as an important means in this respect. Government programs give strong priority to increasing the autonomy and promoting an active lifestyle of elderly people besides institutionalised care for frail ones (CaO 2012, 2014, 2016a; MHLW 2015b; MOF 2016).

Measures that increase the ability to provide domestic care constitute another important policy priority. In fact, the majority of Japan's population at the age of 55 years and above wishes to stay at home until the end of their lives (CaO 2012: 8; see also Figure 2.3). In comparison, a quarter said they wished to stay in hospital, including hospices, whereas just under one-tenth of respondents preferred nursing homes. In other words, the Japanese policy objective of providing care at home coincides with individual preferences. However, the expectation that such care could be provided by family members seems less realistic. Still, a considerable proportion of respondents preferred institutionalised care. However, there is a surprising discrepancy between female respondents (51.8%) and male respondents (37.6%) (CaO 2012: 8). In other words, expectations regarding institutionalised care remain high, especially among elderly female respondents.

---

three responses. (2) "Other" responses by prefectures include "employment creation", "industrial promotion", "integrated and comprehensive support of management and finance" and "promotion of SMEs".

Figure 2.3: Preferred places to live at the end of life (2012, n=1919 people)

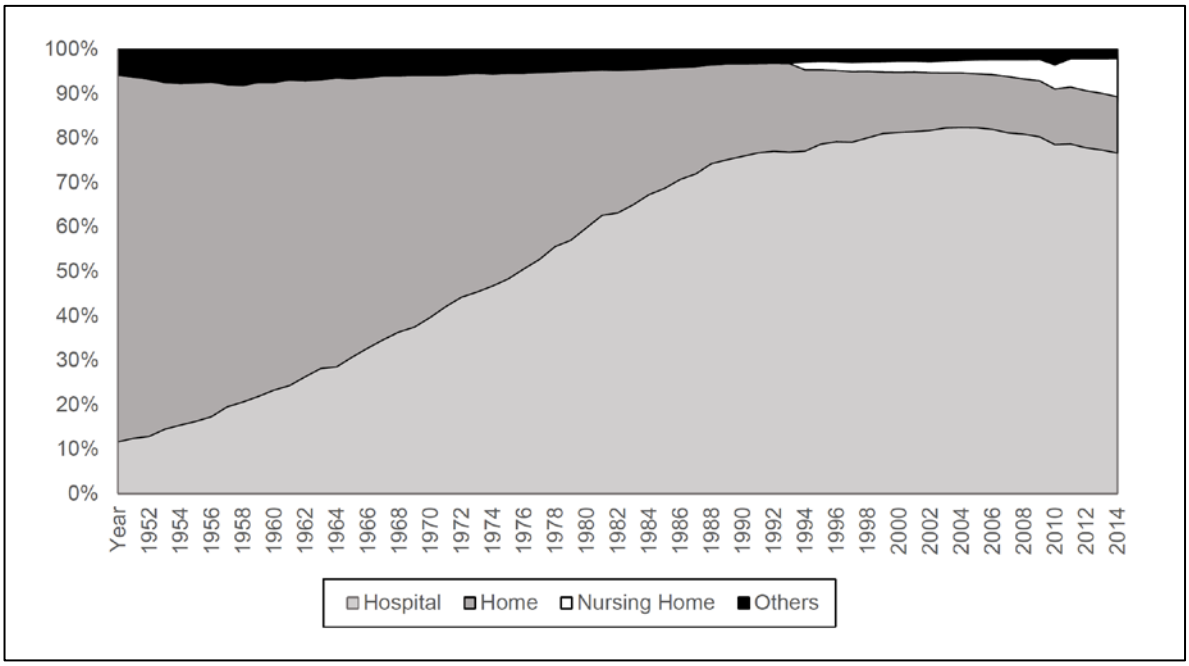


Source: CaO 2012, p. 8.

In reality, however, the majority of Japanese people nowadays still stay in hospital at the end of their life, as shown in Figure 2.4 below. In 2014, 75.2% of people spent the end of their life in hospital and a mere 12.8% at home. In contrast, in 1951, 82.5% of people died at home and only 9.1% in hospital (MHLW 2015b). The recent numbers are obviously in conflict with both individual preferences and public policy goals (compare Figures 2.3 and 2.4).

Figure 2.4 attests to the phenomenon of social hospitalisation (*shakaiteki nyūin*) prevalent in Japan among residents of high ages (70+). According to Campbell (2014: 58–59) “the Japanese government” made “medical care essentially ‘free’ for people aged 70 and older, by reducing their co-payment from 30 or 50 percent to zero” in the early 1970s. In other words, the high number of people spending the end of their life in hospital with “little or no medical justification”, instead of in long-term-care facilities or at home, has become a pressing issue for many municipalities in Japan. Apart from the financial aspect, hospitals are inappropriately equipped for long-term care services in terms of space, personnel and their qualifications, food supplies, daily routines and activities (MOF 2016).

Figure 2.4: Shift in places where the end of life is spent



Source: MHLW 2014b.

For instance, there is insufficient infrastructure and assistance for bathing, eating, privacy, entertainment and mobility in hospitals compared to what is offered in elderly care homes nowadays. Hence, the admission into hospitals of a large group of aged people without medical justification means that they occupy an expensive and inadequate infrastructure designed for acute medical treatment and ill suited to provide long-term care services. The situation has contributed to the surge of unnecessary medical expenditures. At the same time, it raised expectations among elderly people of receiving adequate care at the end of their life in hospital rather than in elderly care facilities.

2.3 The Long-term-care Insurance (LCTI) in Japan

Healthcare insurance for all started in Japan in 1958 (*kokumin kenkō hoken*) and welfare measures for the elderly in the 1960s, when just 6% of the population were 65 years or older. The system was strongly community-based, but provided similar welfare measures throughout Japan, encompassing free access to physicians, a national fee schedule, homes for elderly people and homecare services. At that time, the Japanese state covered the costs for professional caregivers (*hōmu herupā*) or day care services (*dei sābisu*) (Campbell, Ikegami and Tsugawa 2014: 19; MOF 2016). However, the newly established healthcare was

soon confronted with several challenges. One aspect was that elderly people and their families could not choose their caregiving services. All care services available were assigned and provided by municipalities. The quality of care services remained rather low, as there was no competition between different service providers at local level (MOF 2016).

Additional financial pressures were put on the public system after a pre-election promise by the ruling party LDP to cover the medical expenses of the elderly by the state. The law was implemented right before the first oil shock in 1973, causing a surge in healthcare spending ever since. In the end, the decision triggered a growing number of long-term stays in hospitals by elderly residents without medical need. During the 1980s, aged people being looked after in hospitals on a long-term basis increasingly became a social problem (MOF 2016). Naturally, public spending on long-term care continued to rise. Because the government was unable to withdraw favourable policies, it started to manage expenditures by changing the formula to cross-subsidise between various insurers and by capping fees for treatment, devices and drug dispensing. Nevertheless, health expenditures continued to rise and reached 10.2% of GDP in 2013 (Campbell, Ikegami and Tsugawa 2014: 23, OECD 2018a).

With the proportion of elderly people in the Japanese population at more than 12% during the early 1990s, the central government decided to launch a programme called the “Gold Plan” – or the “Ten-Year Strategy for Health and Welfare of the Elderly” – to support long-term-care services in private homes at local and regional level. However, the Gold Plan also proved to be expensive, because it “promised a doubling or tripling of programmes for frail people, all administered by local governments and paid for from tax revenues” (Campbell 2014: 59). The mandatory LCTI was finally enacted in 1997 and introduced in 2000, when 17.3% of the Japanese people were aged 65 or older (MOF 2016, MHLW 2002).

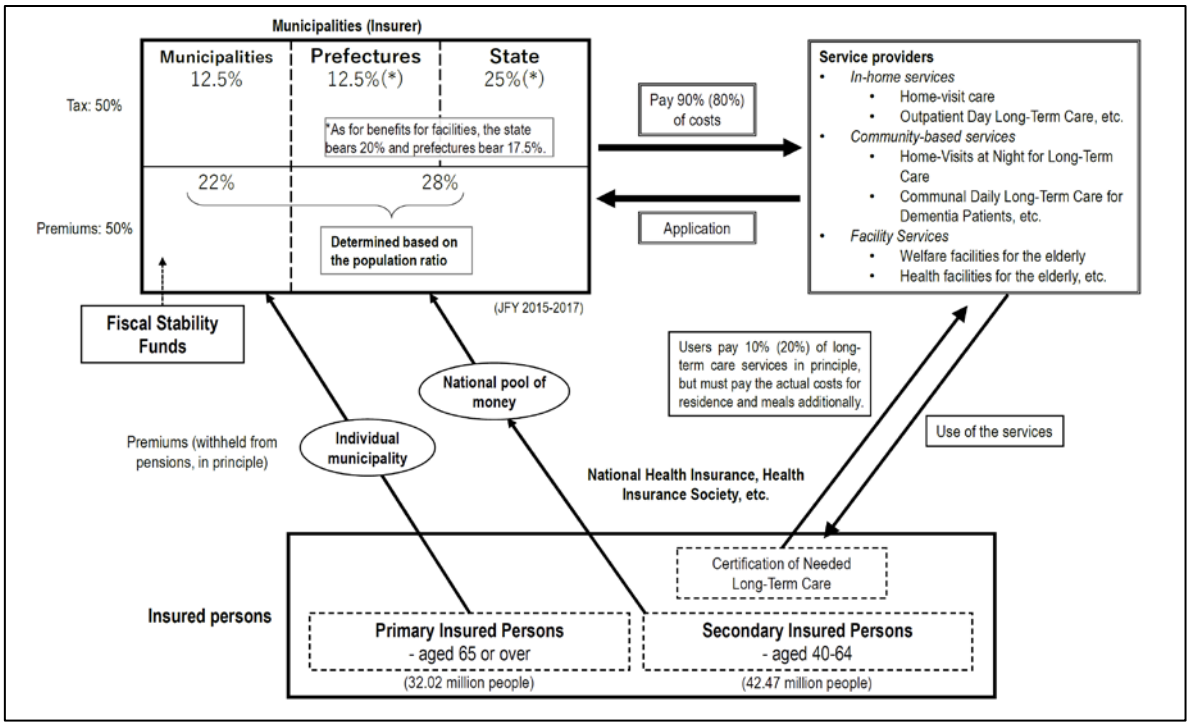
Currently, the MHLW intends to introduce a “community-based integrated care system” (*chiiki hōkatsu kea shisutemu*). One main target is to move towards healthcare services administered at the local level. More specifically, the system is meant to combine medical and long-term care services to generate synergies regarding workforce, services and infrastructure, as well as to avoid unnecessary spending (MHLW n.y. (a)). Under this policy, municipalities and prefectures alike emphasise health maintenance and homecare services as means to reduce public expenditures.

At present, the municipalities play multiple roles in Japan’s healthcare and long-term care systems (Campbell 2014: 58–63; Campbell, Ikegami and Tsugawa 2014: 16–17, 24). Their functions include:

- acting as insurer in the LTCI and in the healthcare system for elderly, self-employed, non-employed and retired residents,
- investing in the care infrastructure and institutions,
- organising institutional care as well as home- and community-based care services,
- certifying the level of care at regional integrated support centres,
- deciding on criteria for allowances on care services and assistive devices,
- monitoring the number and activities of for-profit and non-profit care providers.

As shown in Figure 2.5, 50 percent of the long-term care expenditures are financed by premiums collected from the primary insured people age 65 and the secondary insured group age 40 to 64. The other 50 percent are paid out of tax revenues at the local, prefectural and national level. Municipalities in their function as long-term care insurer reimburse necessary treatments up to 80–90% with a subsequent co-payment of 10–20% by the recipient.

Figure 2.5: Structure of the long-term-care insurance system

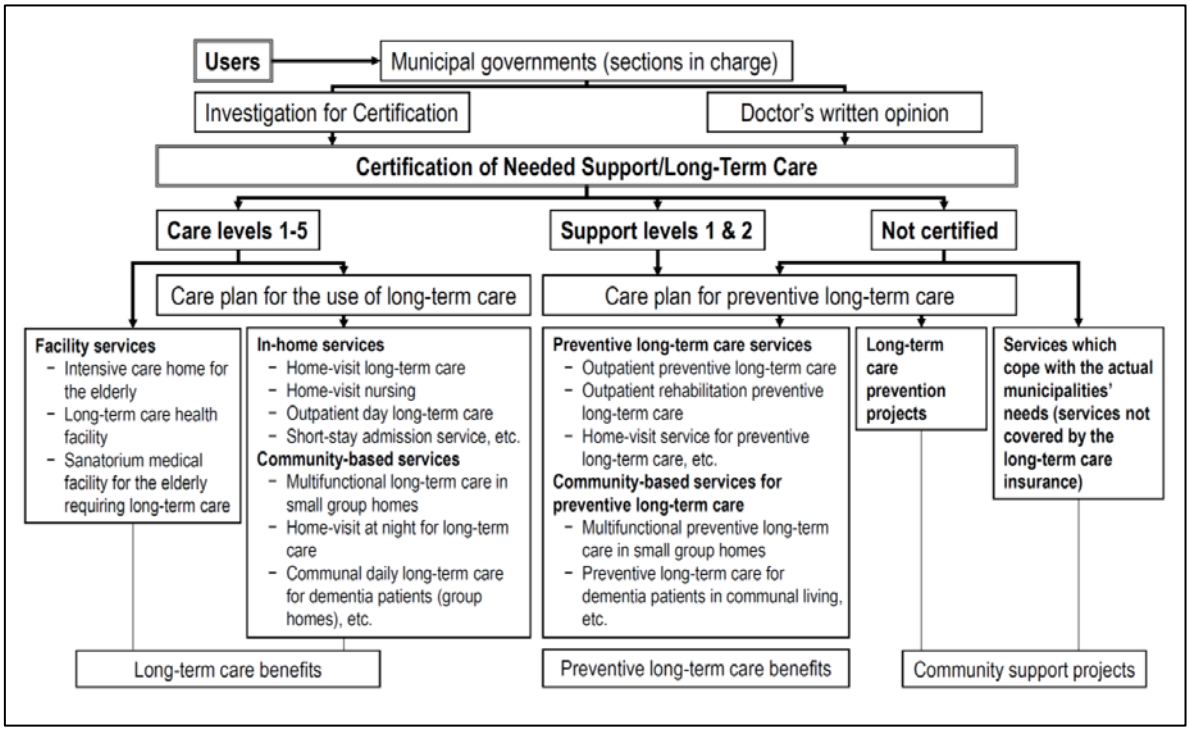


Source: MHLW 2016b, p. 8.

To receive care services requires a certification based on a statement by medical professionals and a procedure conducted by municipalities (see Figures 2.5 and 2.6). If the need for care is certified (*yō-shien no nintei*), a recipient is eligible for long-term care, rehabilitation or preventive measures. The application must be made at regional integrated support centres (*chiiki hōkatsu shien sentā*) with a national standardised questionnaire

evaluating activities of daily life (Campbell 2014: 58). People aged 65 or over or patients between 40 and 65 with special disorders, which are specified by the MHLW (2016b), are also eligible for homecare services. A trained care manager (*kea manejā* or *kaigo shien senmon-in*) visits the residents at their home to assess the necessary level of support (stage 1 or 2) or the level of care (stages 1 to 5) (see Campbell 2014: 63, MHLW 2016b). The care manager also suggests necessary services based on this assessment, ranging from institutional care to community-based and in-home services such as visits, day care or night services (see Figure 2.6).

Figure 2.6: Procedure for assessing an individual's need for long-term-care services



Source: MHLW 2016b, p.10.

Services are divided into preventive measures (*yobō*) and long-term care (*kaigo*). There are day care services provided by prefectures or communities. There are also group homes (*gurūpu hōmu*) maintained by municipalities, which offer rehabilitation measures for inpatients and outpatients. Furthermore, prefectures or municipalities also support mobile rehabilitation services at home according to the level of support or care needed. Homecare services can entail "bathing, dressing, toilet use, transferring in and out of bed and chair, urine and bowel continence, and eating" (Campbell 2014: 58). Recipients can receive consultation and advice from a trained care manager for an individual care plan or for prevention measures and choose between services from for-profit and non-profit care providers at local level.

An increasing amount of services is available to support daily routines and autonomy for aged residents in their homes. In our interviews, we confirmed that developers of domestic healthcare technology take this explicitly into account (see chapter 3 below). Subsequently, homecare appliances and networks have increasingly become included under the reimbursement scheme of the LTCI. Therefore, we need to cast some light on the aspect of how far homecare appliances are integrated under this scheme to learn about possible institutional or financial constraints impeding the implementation of homecare technology.

2.4 Care technologies and their coverage under LTCI

Finding a suitable definition for domestic care technologies is a difficult matter. Nevertheless, a basic distinction can be drawn between medical devices and assistive devices. Medical devices usually require stricter approval standards regarding safety, efficacy and patient's benefit, which implies higher regulatory constraints as far as their certification, liability, usability or exportability is concerned with the effect of potentially lowering the expected return on investment for manufacturers. In the following, we briefly introduce definitions used in Japan and the EU starting with medical devices.[3] We then address the question of coverage of domestic care technologies under Japan's LTCI.

Medical Devices in Japan and the EU

Japan and the EU are members of the International Medical Device Regulators Forum (IMDRF, known as the Global Harmonization Task Force on medical devices, GHTF, until 2011). This voluntary forum with the aim "to discuss future directions in medical device regulatory harmonization" formulated harmonised definitions in 2012 in its final document as the GHTF, GHTF/SG1/N071:2012 (IMDRF n.y., IMDRF/GHTF 2012: 6). According to this document, medical devices are "any instrument, apparatus, implement, machine, appliance, implant, reagent for in vitro use, software, material or other similar or related article, intended by the manufacturer to be used, alone or in combination, for human beings, for one or more of the specific medical purpose(s)." As "specific medical purpose(s)" are listed:[4]

[3] There are additional complexities when it comes to defining when a device can be considered to be a care robot, monitoring sensor system or telehealth network. We address these aspects separately in the respective case study sections.

[4] According to this document, a medical device is one that does "not achieve its primary intended action by pharmacological, immunological or metabolic means, in or on the human

- diagnosis, prevention, monitoring, treatment or alleviation of disease,
- diagnosis, monitoring, treatment, alleviation of or compensation for an injury,
- investigation, replacement, modification or support of the anatomy or of a physiological process,
- supporting or sustaining life,
- control of conception,
- disinfection of medical devices,
- providing information by means of in vitro examination of specimens derived from the human body.

In Japan, medical devices (*iryō kiki*) are similarly defined "as such machinery and appliances (*kikai kigu nado)*, which are either used for diagnosis, medical treatment or prevention of diseases of humans and animals, or which aim at influencing the structure or function of the human or animal body (but excluding products of regenerative medicine etc.) […]" according to the *Yakkihō* (DSSMI, PMDA, Art. 2 § 4).[5] To be recognised and/or certified as medical equipment, a device has to undergo various evaluation(s) regarding quality (*hinshitsu*), safety (*anzensei*) and effectiveness (*yūkōsei*) conducted by the Pharmaceutical Affairs and Medical Device Agency (PMDA).

In contrast, EU regulations regarding medical devices and their certification in the EU are based on directives, which need to be enforced case by case by national authorities or courts (MEDDEV 2010: 1–5, 11, 42–43)[6]. According to the EU Medical Device Regulation (MDR, 2017/745) Art. 2 § 1, medical devices are defined as "any instrument, apparatus, appliance, software, implant, reagent, material or other article intended by the manufacturer to be used, alone or in combination, for human beings for one or more of the following specific medical purposes" (EUR-Lex n.y.). The specific medical purposes can be found in the respective document.

body, but which may be assisted in its intended function by such means" (IMDRF/GHTF 2012: 6). Please refer to the same GHTF document for further specification and national jurisdiction.

[5] *Yakkihō* means *Iyakuhin iryō kiki nado no hinshitsu, yūkōsei oyobi anzensei no kakuho nado ni kan suru hōrei* (Act to Secure the Quality, Effectiveness and Safety of Pharmaceuticals and Medical Devices). The law was last revised on 1 April 2016.

[6] MEDDEV is a set of EU rules for medical devices that specify current EU regulations, assessment and approval for the manufacturer, clinical evaluation and classifications, etc. and, most prominently, the use of the CE mark.

Assistive devices in Japan and the EU

Cowan and Turner-Smith (1999: 325–326) level criticism at the excessive use of the term "assistive technology", which is increasingly employed to describe devices and systems that are "associated with the reversal or amelioration of the declining capacities of older people". Originally, this was an umbrella term for various technologies beyond the context of long-term care or independent living of older people, although nowadays it encompasses any healthcare device, telecare or "gerontechnology" (WHO Centre for Health Development 2004: 10).

Japan distinguishes between assistive equipment and specified assistive equipment. The former is defined as "equipment to aid activities in daily life and for functional training, to assist independence in activities of daily living", whereas the latter is "provided for use in bathing or toilet visits", according to the MHLW (2009: 21, 2011: 1, official translation). Both are again subdivided in two categories:

a) assistive equipment for preventive long-term care (*kaigo yobō fukushi yōgu*) or assistive equipment (*fukushi yōgu*),
b) specified assistive equipment for preventive long-term care (*toku-tei kaigo yobō fukushi yōgu*) or specified assistive equipment (*toku-tei fukushi yōgu*).

The aspect of functional assistance for homecare purposes, prevention and autonomy during daily activities is not explicitly limited to aged people. However, there is also the indication for long-term care, which implies elderly residents as the major target group and long-term-care insurance as the primary source for reimbursement.

In contrast, the Joint Research Centre (JRC) of the European Commission lists "assistive technologies" among various types of homecare devices and systems, such as "technologies for independent living services that include generic information and communication technology (ICT) products", "smart homes" and "technology-based healthcare/home care/wellness services" (Carretero 2015: 13). According to the JRC, "assistive technology"

> *include voice recognition software, text telephones, accessible keyboards, speech recognition software (…), intelligent electric magnifiers and reading lenses, other devices which help the user to drive a car or to participate in sports […], and memory aids on smart phones or tablets. These technologies also include robots, which help older people with physical disabilities to carry out daily life activities or to recover or maintain some capacity. These robots can be prosthetics that replace lost or damaged parts of the body; mobility aids i.e. non-prosthetic technology which replaces or extends the functionality of a leg or an arm; robots for individual training,*

> *exercise and rehabilitation; and robots that carry out logistical and cleaning tasks, and can also be used for personal care (Carretero 2015: 11).*

As in the case of medical devices, the definitions provided by the EU of assistive technologies were more detailed.

Finally, we think the JRC's definition of technologies for independent living services is worth mentioning, too. It extends to ICT-based telehealth systems that are insufficiently addressed in the realm of assistive devices. The JRC refers to them as "all kinds of technology, including Information and Communication Technologies (ICT) that empower older adults to manage their daily life themselves despite their frailties and with quality of life. They also improve the organisation of care provision and increase the productivity and quality of long-term care delivery" (Carretero 2015: 4). We apply this definition in our case studies of the ism-Link network in Iida City (Nagano Prefecture) and the Fukui Medical Net in Fukui Prefecture.

Coverage by the LTCI

The MHLW and other public entities subsidise the development of a large number of care devices. However, to be actually used, these medical and assistive devices need to be rented or purchased from the National Advisory Committee for Assistive Devices (*Zenkoku fukushi yōgu senmon sōdan inkyōkai*, ZFSSK). These care devices have to be designated before their rental or purchase are financially covered under the LTCI (see MHLW 2009, 2011). Table 2.1 gives an overview of devices currently reimbursed under the LTCI. Apart from the requirement of being "designated", the price level for expensive devices has recently be capped to avoid excessive financial burdens (ZFSSK n.y.).[7] This poses a challenge for companies, because the price decides about the future return on their investments in R&D. Low price levels will necessarily reduce R&D efforts.

[7] The price-setting mechanism for healthcare devices by the MHLW is rather complex and cannot be explained further in this report. However, Chapter 5 "Controlling Health Expenditures by Revisions to the Fee Schedule in Japan" and Chapter 6 "The Political Economy of the Fee Schedule in Japan" in the volume entitled *Universal Health Coverage for Inclusive and Sustainable Development: Lessons from Japan* (2014), edited by Naoki Ikegami, include an in-depth discussion of this topic.

Table 2.1: List of examples of devices available for rental and reimbursed under the LTCI

Rental service
▪ **wheelchair** or normal electric wheelchair that is used for care; electric cushion in cases where it belongs to the wheelchair/is part of it; only covered if the elderly person cannot walk on their own
▪ **special bed** with side rails; side rails for bed if they can be attached; mattress in cases where it belongs to the bed/is part of it; beds are eligible if they allow the back or feet of the user to be inclined; beds are eligible if the mattress can be steplessly adjusted; only covered if the elderly person cannot get up/move on their own or is bedridden
▪ **air cushion** to prevent bed sores, only air cushions that can handle body/air pressure, have air-cooling features and cannot be damaged by water; only covered if the elderly person cannot walk on their own
▪ **seat cushion** to support good posture, if it enables people to easily shift their seating position; not covered if it only helps them to maintain their position; only covered for bedridden people
▪ **hand rail**, ramp if no construction is required
▪ **mobility aids/walking assistant** that has a hard, stable handrail/frame surrounding the user, must have four wheels and be used/held with hands when walking; automatic walking assistants are covered if they fulfil these conditions (also if they assist braking/walking uphill)
▪ **walking aids**, only special types of crutches
▪ **sensor** for monitoring elderly people suffering from dementia (sends message if the person goes outside), only covered for people who have been certified as suffering from dementia/memory loss etc.
▪ **lift** excluding hinge, only lifts that do not require structural alteration for installation; only covered if the elderly person cannot get up on their own
▪ **automatic excretion machine** only if its use is easy for care recipients/families and parts (e.g. receiver, tube, tank) can be easily replaced by them if necessary; only covered if the elderly person needs help to go to the toilet (certification after assessment)

Source: ZFSSK n.y.

As far as “robotic devices” are concerned, the ZFSSK (n.y) offers a rental service for smart wheelchairs or normal electric wheelchairs. The general functionality and safety are decisive factors for whether devices are included in the fee list. For example, a hospital-type bed for homecare can be rented if it has side rails, or if side rails can be attached to it. Additionally, beds are only eligible for financial support if they allow the back or the feet of the user to be inclined and if the mattress can be steplessly adjusted. Another example are mobility aids, which can be rented under LTCI on the condition that they are equipped with a hard, stable handrail or frame surrounding the user. Furthermore, they must have four wheels and be held with both hands by the user when walking. Automatic walking assistants which can brake and slow down the pace while walking downhill or assist walking uphill will also be reimbursed if they fulfil the above-mentioned specifications. Respective features proved essential in the certification of the robot assist walker RT.1 and its later models, which were first excluded and later included in the fee list (see chapter 3.2).

Finally, there are several devices that the ZFSSK offers for purchase under the LTCI for hygienic reasons or in cases where they are designated as special assistive devices by the MHLW (see MHLW 2009, 2011). However, the classification as special assistive devices and their inclusion under the fee list depend on the assessment by the ZFSSK. For instance, the advisory committee sells and redistributes care products that include robotic care devices, such as automatic excretion machines, as well as non-robotic care appliances, such as hinges that can be attached to lifts or bathtubs or bathing aids.

Table 2.2: List of devices offered for purchase

Available for purchase
▪ toilet: (non-)flushing and Japanese/Western style types are covered if they can be used in single/separate rooms; coverage depending on the costs
▪ automatic excretion machine (criteria: see above)
▪ bathing assistance tools, e.g. chairs (higher than 35 cm that can be reclined), belts
▪ bath tub: must be simple and not require construction/structural alteration, must be filled with air or foldable to be easily moved, no hard material
▪ hinge that can be attached to a lift, appropriate for lifting elderly people

Source**:** ZFSSK n.y.

There are many criteria, which both robotic and non-robotic care products such as transfer assistance lifts, wheelchairs and automatic excretion machines or monitoring sensor systems must fulfil to be covered by the LTCI. Naturally, priority is given to support robotic care devices that are safe and easy to use and to repair. However, as our case studies showed, even if a device is safe, easy to use and more efficient in supporting elderly people in their everyday lives, it will not be included under the LTCI, if it does not comply with all the criteria specified by the ZSSK (see chapter 3.2 for further detail).

3 Case Studies of Domestic Healthcare Technologies

This chapter introduces our case studies of prevalent types of domestic healthcare technologies in Japan: care robots, monitoring sensor technology and ICT-based telehealth systems. As mentioned above, the case studies were guided by the following research questions:

- **Material Dimension:** *What kind of domestic healthcare technologies can be found in Japan? What stage of development or implementation can be observed?*

- **Social Dimension:** *What added value do domestic healthcare technologies generate from the perspective of users and developers?*
- **Financial and Regulatory Dimension:** *What financial and regulatory requirements do domestic healthcare technologies face?*

The first two questions address the material dimension, i.e. the functionality and design of respective devices. The third question looks at the social dimension. It comprises the motivation of the developer and manufacturer and the acceptance of the technology by users. The last question considers the financial and regulatory dimension, i.e. the regulatory and financial constraints manufacturers face when selling their technical solutions. Before presenting the results of the case studies, we briefly explain the research design.

3.1 Research Design

This research is based on statistical sources, interview studies and a comparison of three types of domestic healthcare technologies. The qualitative interviews and various on-site visits were conducted between March and July 2017.

Selection of domestic care technologies

Our goal was to cover different types of technologies. Specifically, we wanted to focus on the three dominant types of domestic healthcare technology in contemporary Japan, which fulfilled the following two core criteria:

- applicability in the context of healthcare,
- practicability to be used in private homes.

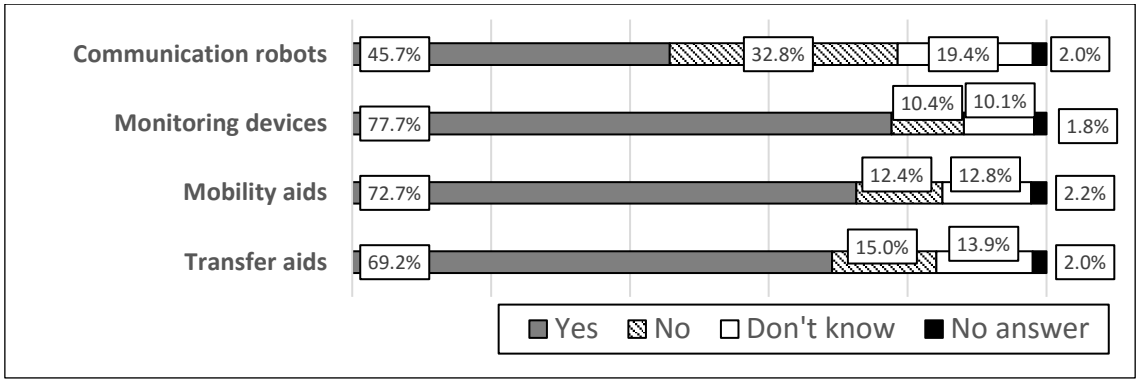
In addition, we took into account the level of advancement of the technology, its stage of development or implementation and its level of diffusion. Our investigation led us to choose the following three dominant technologies for our case studies:

- care robots,
- monitoring sensor systems,
- ICT-based telehealth systems.

Selection of cases and interview partners

Within the given time restrictions, we wanted to conduct at least one case study for each type of technology. We also wanted to include implementations in peripheral regions. The choice of cases finally depended on the accessibility to the field, i.e. on the willingness of potential interview partners to meet with us and answer our questions. Regarding the field of care robots,[8] we excluded devices, which provide merely a communication function. Although these devices are strongly supported by the Japanese government and have received wide scholarly attention within Japan and abroad (see Robertson 2017, Sone 2017, Wagner 2010 and 2013), they are in many cases still under development, and seem to be predominantly used in institutionalised care facilities.

Figure 3.1: Willingness to use robotic care devices (N = 2,602 nursing facilities, Tokyo)



Source: Tokyo Metropolitan Government 2016, p. 20.

Also important for our selection was the fact, that they are ranked lowest (45.7%) by professional caregivers in comparison to other devices that they are willing to use in their daily care work (see Figure 3.1). We finally chose care robots from the field of smart mobility aids, which have a very high acceptance rate according to the same survey (Figure 3.1). Our study covers the wheelchair-bed Reshone by Panasonic, the assist walker RT.1 by the RT.Works and the Tsurube B lift, which can be attached to a hospital-type bed (see Chapter 3.2 for further detail).

[8] See Chapter 3.2.1 for an in-depth definition.

Table 3.1: List of interview partners and/or on-site visits

Interview partner	Position and function of interviewee(s)	Date of interview / on-site visit
Care Robots and Robotic Care Devices		
National Institute of Advanced Industrial Science and Technology (AIST)	representative (researcher, engineering science) Robot Innovation Research Center / Robot Safety Center	24 March 2017 Tsukuba City, Ibaraki Prefecture
Mobilika demonstration of RT.1 assistive walker	representative (sales person)	01 May 2017 Tokyo
On-site visit to a transfer lift attached to hospital-type bed for homecare	bedridden elderly person caregiving spouse care manager	28 June 2017 Kamakura City, Kanagawa Prefecture
Panasonic (Age-Free Business Unit)	representative (developer, engineer)	12 July 2017 Tokyo
Monitoring Sensor Systems		
Sekisui House, Ltd.	manager (developer, engineer)	28 July 2017 Koga City, Ibaraki Prefecture
ICT-based Telehealth systems		
Fukui Medical Net	Fukui Medical Association ▪ executive board member ▪ representative of planning department Fujitsu (Healthcare Systems) Fukui Prefecture (Prefectural Administration)	27 April 2017a Fukui City, Fukui Prefecture
Fukui Prefecture	Fukui Prefecture (Prefectural Government) ▪ representative of healthcare and welfare unit ▪ project manager	27 April 2017b Fukui City, Fukui Prefecture
ism-Link of Iida City	Iida City Municipal Hospital ▪ representative of regional medical collaboration unit ▪ representative of regional medicine department Iida City Healthcare Welfare Unit	24 July 2017 Iida City, Nagano Prefecture

As for monitoring sensor systems (*mimamori sensā*), we were able to conduct one interview with a developer in the field and were able to visit Sekisui House, one of the largest private house builders in Japan and manufacturer of smart house solutions. Regarding ICT-based telehealth systems, we were able to conduct interviews and undertake on-site visits in the cities of Iida, Nagano Prefecture, and Fukui, Fukui Prefecture. Both are located in the peripheries of Japan.

The case studies were carried out between March and July 2017. Due to difficulties in accessing the field and time constraints, we mainly conducted interviews with developers and implementing organisations together with on-site visits or demonstrations. Table 3.1 lists

the interview partners and on-site visits undertaken for this project. Apart from them, we analysed additional published and unpublished documents we obtained for each of the cases.

Interview guide

The interviews were based on a semi-standardised list of questions (Table 3.2). Items referred to the material dimension (features and functions), the social dimension (motivation by developers and acceptance by users) and the financial and regulatory dimension. Nevertheless, the interviewees were encouraged to provide freely additional insights from their experiences with the respective domestic care technology.

We discussed the research design including the interview guidelines with experts from healthcare science, practitioners and Japan experts and revised it accordingly.

Table 3.2: Basic structure of interview guide

Codes	Questions
O	Opening part
M1 M2 M3 M4	Material Dimension o characteristic features of the device or system (e.g. purpose, stage of development or implementation, maintenance, usability, added value regarding conventional solutions and similar devices) o special preconditions required to operate the device or system (e.g. domestic living environment, third-party assistance, infrastructure) o users' benefit (imagined users/target group, feedback on users' needs and expectations, concerns, complaints about difficulties or malfunctions, trials) o level of comprehension of the device or system (e.g. users, families or supporters, training, after-sales support)
S1 S2	Social Dimension (stakeholders) o development process of the device or system (e.g. motivation, initiator, collaborator and supporter) o implementation process (e.g. further interest groups, motivation, type of support)
R1 R2	Financial or Regulatory Dimension o financial requirements of the device or system (e.g. financiers, ownership, reimbursement by health insurance or long-term-care insurance, financial support, subsidies, sponsorship, time requirements and manpower, or professional assistance to operate the system) o institutional requirements (e.g. regulation)
O	Closing part

In the following, we present our findings by closely following the answers we received in the interviews. We will report on the user feedback that manufacturers gained through field tests

and demonstrations of their homecare technology in order to respond to the third research question (social dimension). In presenting the cases, we follow the basic structure of the interview guide addressing the material and social dimensions as well as financial and regulatory dimension separately. This enhances the comparability between the different types of devices.

3.2 Care Robots and Robotic Care Devices

Our interviews confirmed that the understanding of care robots is ambiguous. This is the major reason why we examine this point in detail at the beginning of this chapter. Next, we focus on the robotic wheelchair-bed *Reshone*, developed and commercialised by Panasonic Age Free, and the Robot Assist Walker RT.1, developed by enterprise RT.Works and distributed by the company Mobilika.

Apart from the case studies, we were also able to conduct an interview at the Robot Safety Center (*seikatsu shien robotto anzen kenshō sentā*) in Tsukuba City, Ibaraki Prefecture. This centre develops and conducts tests and certification procedures on safety (*anzen-sei*) and effectiveness (*yūkō-sei*) of various categories of care robots and robotic care devices before they are allowed to be introduced to the market. The centre was a valuable source of information regarding the current situation of care robots in Japan (e.g. stage of development, practicality, regulatory constraints). The centre has approved robots, promoted by governmental organisations such as NEDO and AMED, two Japanese robot project, as well as devices from several manufacturers such as Panasonic Age Free or the Robot Assist Walker developed by RT.Works (interview, 24 March 2017).[9] In addition, we gained insights from an on-site visit at a private home in Kanagawa Prefecture regarding the Tsurube series B-set lift (*Tsurubē shirīzu B-setto*, short: Tsurube B) produced by Moritoh Corporation. The on-site visit to the private house and the interview at the Robot Safety Center provided additional insights for the second research question (stage of development) and the third and fourth one (added-value and constraints).

[9] In addition, the representative of the Robot Safety Centre mentioned other robotic care devices, such as the Walking Assist from Honda, the autonomous delivery robot HOSPi from Panasonic, the HAL suit from Cyberdyne, the transfer assistance robot SASUKE from MUSCLE Corp., the automatic excretion processor produced by several different companies or the bedside water closet from TOTO (interview, 24 March 2017).

3.2.1 Background: Defining Care Robots and Robotic Care Devices

The understanding of what constitutes a care robot remains ambiguous between experts and the public. The definition and images of robots seem to be influenced and change over time and vary across disciplines as well as the language used – in our case English and Japanese. It also depends on the expectations of laypeople and popular images created by the mass media. This aspect was emphasised during the interviews and we decided, therefore, to discuss it first.

Commonly shared attributes of robots are that they possess a CPU (central processing unit) and an actuator, which is responsible for moving and controlling a mechanical system. Moreover, the interviewee at the Robot Safety Center expressed the opinion that there might be images of robots in Japan that differ from those prevalent in European countries or the United States. Nevertheless, he stated that he was frequently asked by laypeople if an object such as a bed or wheelchair, which does not look like a robot, was still supposed to be one. Furthermore, he argued that automotive machines such as cars have recently been "robotised" as well. This could be a reason, in his opinion, why the definition of robots could be increasingly extended to devices such as vending machines or assistive equipment such as automatic excretion machines (interview, 24 March 2017).

According to the Ministry of Health, Labour and Welfare (MHLW) in Japan, a robot is defined as an intelligent mechanical system that entails the following three technological elements:

a) sensor unit: function of sensing information (情報を感知: センサー系, *jōhō o kanchi: sensā-kei*),
b) intelligence-control unit: function of interpreting information (判断し: 知能・制御系, *handan shi: chinō-seigyō-kei*),
c) drive unit: function of performing tasks (動作する: 駆動系, *dōsa suru: kudō-kei*).

The ministry stated that "subsequent devices can be called care robots [*kaigo robotto*] if they are utilised in the context of healthcare" (MHLW 2016a). Care robots fulfil the function of assistive devices similarly specified by the MHLW and the European Commission (see AIST n.y. (a) and Chapter 2.4 for detail). However, the use of the term *kaigo robotto* lacks clarity because, in Japanese, there is no distinction between care robots and robotic care devices, whereas there are two different terms in English.

On the other hand, the International Organization for Standardization (ISO 2014) distinguishes between *robots* and *robotic devices*, according to its standard ISO 13482:2014(en). This technical standard was strongly influenced by the Japanese Ministry for Economy, Trade and Industry (METI) and NEDO and Japanese care robots were among

the first devices certified under this standard (METI 2014a, METI 2014b). According to the ISO, a robot contains an "actuated mechanism programmable in two or more axes with a degree of autonomy … moving within its environment, to perform intended tasks" (3.2), while robotic devices refer to an "actuated mechanism fulfilling the characteristics of an industrial robot or a service robot…, but lacking either the number of programmable axes or the degree of autonomy" (3.3). In this context, autonomy is understood as the "ability to perform intended tasks based on current state and sensing, without human intervention" (3.1). These specifications strongly resemble the three elements listed in the MHLW definition of *kaigo robotto*, which also includes the feature of *autonomy*.

Furthermore, the same standard on "Robots and robotic devices – Safety requirements for personal care robots" specifies the categories of (3.4) service robots, (3.5) mobile robots, (3.13) personal care robots, (3.14) mobile servant robots, (3.15) physical assistant robots and (3.15.1) restraint-type physical assistant robots, as well as (3.16) person carrier robots. Against the backdrop of domestic healthcare, the category of *personal care robots* with its subsequent categories (3.14), (3.15), (3.15.1), and (3.16) are of most interest for this report. More precisely, these categories are defined according to the standard ISO 13482:2014(en) as follows:

- A **personal care robot** is a "service robot […] that performs actions contributing directly towards improvement in the quality of life of humans, excluding medical applications", (e.g. typical types of personal care robots include mobile servant robot, physical assistant robot and person carrier robot) (3.13).
- A **mobile servant robot** is a "personal care robot […] that is capable of travelling to perform serving tasks in interaction with humans, such as handling objects or exchanging information" (3.14).
- A **physical assistant robot** is a "personal care robot […] that physically assists a user … to perform required tasks by providing supplementation or augmentation of personal capabilities" (3.15). The sub-category of a **restraint-type physical assistant robot** is defined as "physical assistant robot … that is fastened to a human during use" (e.g. wearable suits or non-medical physical assistance exoskeletons) (3.15.1).
- A **person carrier robot** is "personal care robot […] with the purpose of transporting humans to an intended destination" (3.16).

Specifically, devices such as (a) transfer aids (*ijō kaigo*), (b) mobility aids (*idō shien*), (c) toileting aids (*haisetsu shien*), (d) monitoring systems (*mimamori*) as well as (e) bathing aids

(*nyūyoku shien*) are all listed as care robots on the Japanese website on “robot care” (see AIST n.y. (a) and Chapter 2.4). However, these assistive technologies encompass predominantly robotic care devices for the purpose of disabled and aged care, which are distinguished more clearly under the ISO definition than in the MHLW definition on *kaigo robotto* (care robots) or on the Japanese website on robot care.

For the purposes of this report, our understanding of care robots will be restricted to an actuated mechanism programmable in two or more axes, which senses information and interprets it, and which autonomously performs the intended tasks for the purpose of care without human intervention. We differentiate care robots from robotic care devices according to the ISO definition, as the former are “programmable in two or more axes with a degree of autonomy” and the latter are “lacking either the number of programmable axes or the degree of autonomy“. Moreover, we do not consider monitoring sensor systems as care robots or robotic care devices in the narrower sense because they are not a device equipped with a drive unit conducting movements, but are closer to an ICT system. We, therefore, classify monitoring sensor systems as a different type of technology and examine them in Chapter 3.3. Hence, we have chosen smart mobility aids such as the RT.1, transfer aids such as the Tsurube B lift and hybrid categories such as the robotic wheelchair-bed Reshone as representative and recently developed robotic devices in the context of domestic healthcare.

3.2.2 Material Dimension

First, we present results regarding the material dimension. Specifically, we document information about the technical features and functionality for a homecare setting of the transfer assistant lift Tsurube B, the wheelchair-bed Reshone, and the Robot Assist Walker RT.1.

The transfer assistance lift Tsurube B

We need to keep in mind that female caregivers conduct most care work in Japan (see Campbell 2014: 61) and that lower back pain is one of the most frequent occupational diseases in professional long-term care. For instance, 42.4% of male and 56.6% of female outpatients suffered from lower back damage, according to the “Basic survey of Japanese people’s lifestyles” (*Kokumin seikatsu kiso chōsa*) published by the MHLW (2017b: 19). This underlines the need for transfer aids to prevent an additional burden on caregiving staff when moving bedridden or frail people.

Picture 3.1: Transfer assistance lift Tsurube B-set attached to a hospital-type bed.
© Susanne Brucksch

Lifts seem to be not yet common in most nursing homes and private houses in Japan, since they are frequently considered to need too much space (on-site visit, 28 June 2017). Instead, caregiving relatives and nursing staff have to lift disabled people themselves, which easily leads to back damage and psychological stress (interview, 12 July 2017). In comparison, the transfer assistance lift Tsurube B, produced by the company Moritoh Corporation, was designed to lift people out of their beds and into a chair or wheelchair alongside (Moritoh n.y.). The lift Tsurube B can be used for a weight up to 100 kg, and is installed next to a hospital-type bed (see picture 3.1). It needs about 1 to 2 metres radius to be able to turn 360 degrees. The distributor installed the lift and explained its functions to the patient's family during our visit. The installation and the introduction of the device took only two hours (on-site visit, 28 June 2017). The device is easy to us and fulfils its function of allowing the transfer of a bedridden person with only one person assisting, and represents, therefore, a low-threshold device regarding acceptance by users in need of this kind of homecare.

The robotic wheelchair-bed Reshone by Panasonic Age Free

The manufacturing company Age Free, a subsidiary of Panasonic, founded in 1998, has developed and distributed robotic care devices, such as digital mirrors for rehabilitation to train elderly people's cognitive skills, toileting and bathing aids, hand rails, unit baths (factory-produced bathroom modules) and entire rooms that are barrier-free. They display their products in showrooms and in care centres such as in Kanagawa Prefecture. Until 2016, Age Free has been steadily growing and its sales at the time of the interview totalled 3.4 billion yen (interview, 12 July 2017; Panasonic n.y. (a), n.y. (c)). Apart from developing care robots and making them available for rent or purchase, Panasonic Age Free offers a number of other services, such as operating almost 130 care shops (*kaigo shoppu*) throughout Japan to sell or rent out their products, care centres with outpatient care and "short stays" (*shōto sutei*) and houses with apartments to host elderly people. According to the interviewee, they also offer a repair service for products in private households at their shops (interview, 12 July 2017).

As for care robots, the company mainly focuses on devices providing mobility or person carrier assistance. Panasonic Age Free has been developing robotic care devices for over 20 years with different purposes and to be used in both private households and care centres (interview, 12 July 2017). At present, the best-selling product is the robotic wheelchair-bed *Reshone*,[10] which they literally call an "uprising assist robot" (*rishō ashisuto robotto*). The main feature of Reshone is moving a bedridden person into an upright position by transforming into a wheelchair, which then allows the user to move around the house (see picture 3.2 and 3.3). The wheelchair-bed is about 90 cm wide and designed to look like a normal bed or wheelchair, easy to use and space-saving (interview, 12 July 2017; Panasonic n.y. (b)).

According to a developer from Age Free, transfer robots are used to move elderly people, as transfer is difficult and lifts are seldom used in Japanese care facilities. Instead, caregivers have to move bedridden people by their own physical strength from bed to wheelchair and often with the need of multiple caregivers. Age Free actively started to advertise this care product in March 2017 (interview, 12 July 2017).

[10] The developer derived the name Reshone from the Japanese word *rishōne* combining the characters for "getting-up" and "sleeping". Alongside "Reshone", the company also uses the alternative romanisation of "Resyone", which does not clearly convey the correct pronunciation in English. This is why we prefer the former spelling for the wheelchair-bed (Panasonic n.y. (c)).

Picture 3.2: Reshone as a bed.

Picture 3.3: Transformed into a wheelchair.

© Susanne Brucksch

In addition, the bed turned out to be faster at transferring people than a lift. The same tasks could be conducted by the care recipients themselves in a quarter of the time needed previously. Therefore, the interviewee evaluated the bed as a case of “best practice”, as it increased efficiency in terms of time, reduced physical stress and the human resources required and raised quality of life and personal autonomy (interview, 12 July 2017; Panasonic n.y. (b)). In fact, Reshone received the Best Practice Award for Introducing Care Robots 2016 (*Kaigo robotto dōnyū kō-jirei hyōshō jigyō 2016*) (ATA 2016: 10).

Robot Assist Walker RT.1

In contrast to the person carrier robot produced by Panasonic Age Free, which supports the transfer of elderly people who are no longer able to walk, the company Mobilika distributes mobility aids and walking assistive devices to people still able to walk. One of their appliances is the walking assistance robot RT.1 (*hokō ashisuto robotto RT.1*). Model RT.1 received the 7th Robot Prize in Japan in 2016. The subsequent model RT.2 obtained the Good Design Award 2017 (Good Design Award, n.y.; Mobilika 2017a; Robot Award n.y.). The awards indicate the readiness for market and significance of the devices as assessed by an external jury. Accordingly, among all the care robots in Japan certified by the Robotic Safety Center, the walking assistant RT.1 was obviously one of the best-selling devices, as about 3,000 assistive walkers had already been sold throughout Japan at the time of the interview, according to the representative (interview, 24 March 2017).

Picture 3.4: Robot Assist Walker RT.1 in operation.

Picture 3.5: RT.1 folded for storage at home.

© Susanne Brucksch

The RT.1 was advertised as easy to operate, with its location easy to track by an integrated GPS system. The assistive walker entails 6-axis motion sensors and 4 wheels with separate engines and weighs about 10 kilos, which makes it easy to carry (see picture 3.4 and 3.5). The device also monitors stride length and number of steps (interview, 1 May 2017). Moreover, the device brakes automatically if one hand stops holding the handles. It is able to inform nursing staff or families via ICT network data if its user falls or collapses and about the charging state of the batteries. What is more, the assistive walker collects data that can be uploaded and stored on a server, only accessible to registered users. If technical problems occur, the distributor is informed via an automatic message (Mobilika 2017b; RT.Works n.y.).

3.2.3 Social Dimension

After examining the material features of the robotic care devices examined, we cast light on the social dimension in this section. We received statements about the engineers' motivation for the development of the devices, the various stages of designing an adequate device and various quotes regarding users' feedback. Because the interview at Panasonic Age Free generated most output, we present mainly the narrative concerning the process of development of the wheelchair-bed Reshone.

Purpose of development

Basically, interviewees identified Japan's ageing population and the need to support the lives of elderly people at home as their main incentive for doing R&D in the field of homecare appliances. In their opinion, this situation has been also the main driving force for the government to support the development and use of care robots. Therefore, the main goal expressed by developers of care robots was to support elderly people regarding everyday situations and rehabilitation and to thereby assist both caregivers and recipients (interviews, 24 March 2017 and 12 July 2017). In this way, care robots and robotic care devices are perceived as a means to achieve healthcare and long-term care policy goals to allow disabled and frail people to continue living as independently as possible.

Development efforts also aim at easing the physical burden and the psychological stress of care personnel and families. Against the backdrop of a growing labour shortage, developers encompass approaches to make care services more efficient with the use of their devices (interview, 24 March 2017). For instance, a sanitary installations manufacturer developed an automatic excretion device with the explicit goal to reduce stress for caregivers and their families, as caregivers would not have to get up during the night, if elderly people were assisted to use the toilet independently (interview, 24 March 2017). According to the interviewee, the motivation of developers was fuelled and ideas for assistive devices could be specified based on experiences during on-site visits to private households or nursing homes. Engineers developing the devices were able to reconsider the necessity and practicality of their concepts in a homecare context and the various aspects and tasks of caregiving (interview, 24 March 2017).

Developing the transfer assistance robot Reshone by Panasonic Age Free

The representative of the Robot Safety Center emphasised that a device needs acceptance by users, as well as approval by regulatory authorities. Especially if the robot will be used in public, it has to be designed to look like ordinary clothing, such as tights, or an assisting device, rather than a robot. Consequently, the interviewee explained, the social setting and intended service design of an envisioned robotic device should be considered first, before the engineering of the mechanical design was conducted (interview, 24 March 2017). Otherwise, it is highly likely to fail to become widely accepted and successfully implemented.

In the case of Reshone, the developing team at Panasonic Age Free first designed a prototype, which was designed as a transfer assistance robot (TAR). This transfer robot was developed between 2005 and 2010 with financial support from the government. It consisted

of a scaffold structure with two pillars directed towards the front. The caregiver was supposed to carry a bedridden person while standing between these arms facing the care recipient. However, the original transfer assistant robot turned out to be too bulky, occupying up to more than two metres of space to turn and additional space for storage when not in use. Therefore, the TAR became considered impractical for homecare settings and elderly homes alike (interview, 12 July 2017).

The TAR was also never sold as a commercial product because developers faced safety problems when carrying and transferring bedridden people. What is more, developers did not come up with a belt to hold the carried person attached tightly enough to the transfer component. In addition, there were mounting problems with weight distribution and the stability of the construction. Consequently, caregiving staff and recipients did not perceive the prototype as safe (interview, 12 July 2017). Therefore, the subsequent version of a transfer assistance robot already resembled a robotic bed (*robotikku beddo*). The model was operated by pressing buttons. However, the Robot Safety Center was not able to issue a certification for this prototype, as users could have accidentally trapped their fingers when pressing these buttons. This was why the developing team at Panasonic Age Free had to redesign the wheelchair-bed a number of times (interview, 24 March 2017).

Eventually, a prototype was tested in care homes in Denmark, as a frequent target country for several Japanese manufacturers of robotic care devices. The interviewee reported that the prototype received positive feedback from many users there, because the device could be operated individually by the user and contributed to their autonomy (interview, 12 July 2017). Based on this positive feedback, the developers at Panasonic Age Free continued development with a fully automated wheelchair in mind. Eventually, one more prototype was exhibited at the International Home Care and Rehabilitation Exhibition in 2009 in Tokyo, receiving repeatedly positive feedback from disabled people, despite having been primarily targeted at elderly people. After developing a transfer robot designed as a bed or a wheelchair, developers at Panasonic Age Free came up with the idea of integrating the two different categories into one assistive device by inventing their best-selling device Reshone, which can be both bed and wheelchair (interview, 12 July 2017).

Obtaining feedback on the transfer assistance lift Tsurube B

The transfer assistant lift attached to a hospital-type bed was developed by Moritoh for a purpose similar to that of the wheelchair-bed. The three users of the lift called *Tsurube B* reported they had used the lift to move the bedridden person out of bed and into a wheelchair.

Specifically, the spouse felt relieved by being enabled to assist her 95-year-old husband to transfer from his bed into the wheelchair, particularly when no second caregiver was present to help. As the bedridden man's ability to move on his own was restricted, he mentioned during the visit that everyday life "became easier" (*raku ni natta*) (on-site visit, 28 June 2017). Nevertheless, the private home we visited was exceptionally spacious and the hospital-type bed with the attached lift was already installed in the living room, occupying a lot of space. In confined Japanese residential houses, the installation of a transfer lift might be somewhat more difficult.

The user's feedback about the device was rather positive. In addition, his spouse said that there was nothing in particular about the lift that needed further improvement. She emphasised the importance of inclining the wheelchair by 45 degrees when lifting the carried person from bed to wheelchair. Furthermore, she explained that she could still use the Tsurube B, as she could incline the wheelchair as necessary when lifting her husband from bed to wheelchair. Finally, the caregiving spouse especially expressed concerns about what might happen in case of a power failure during use, especially at the point when the transferred person is being moved (on-site visit, 28 June 2017). In addition, even though transfer by the lift appeared comfortable and easy to handle for the patient and the caregiving spouse, the inclination of the wheelchair and the necessary use of the sling-seat may leave some room for some improvement.

Obtaining feedback on the robotic wheelchair-bed Reshone

Representatives from Panasonic Age Free and the Robotic Safety Center stressed the importance of learning users' needs from experiencing actual situations of long-term care in nursing facilities and private households. More precisely, they stressed that surveys among general customers were less efficient in gaining insights, because general questionnaires would only reproduce answers referring to typical images of robots, but would not lead to devices applicable for healthcare purposes (interviews, 24 March 2017 and 12 July 2017). Most customers of Age Free are from medical support and healthcare businesses. Panasonic Age Free offers training on their devices to nursing and care staff in order to raise awareness of robotic care devices as useful tools. The interviewee stated that this training seemed to be necessary because the nursing and care staff were frequently concerned that they would not benefit from such devices but saw them rather as only taking up space (interview, 12 July 2017).

The interviewee pointed out that there are young people, particularly young men, who generally think robots are fun (interview, 12 July 2017). However, care workers preferred robots which do not resemble “popular images” of robots such as humanoid or entertaining companions, but which are “normal” and “appropriate” within the setting of long-term care and homecare (see also Chapter 3.1). Having said that, the interviewee explained that caregivers and care recipients simply wanted a convenient device and that care robots were specifically designed with those involved in caregiving in private households or care institutions in mind (interview, 24 March 2017). The developer at Panasonic Age Free also reported that user feedback for care robots always included requests for the safety of the devices (interview, 12 July 2017).

In addition, they conducted internships in care homes to understand the problems faced by users of homecare robots and robotic care devices. They conducted tests with the robotic bed Reshone in an actual care home. Afterwards, a survey among 118 care workers who had used the wheelchair-bed for three months was conducted. The care workers reported up to 70% less back pain and psychological stress, as they were no longer forced to lift bedridden people themselves (interview, 12 July 2017).

Consequently, the various feedback led to the decision to design products at Age Free to adapt the design and colour scheme of the Reshone wheelchair-bed to a brown pattern that strongly resembles living room furniture, and to limit the number of buttons (easy to use) to ensure low-threshold usage in the stressful working environment of professional caregiving (on-site demonstration, 12 July 2017). Product design was thus clearly altered during the development process in accordance with users’ needs.

Obtaining feedback on the robot assist walker RT.1

As mentioned earlier, the Robot Assist Walker RT.1 collects data that can be uploaded and stored on a server. However, the interviewee mentioned briefly that some aged users did not wish their children to have access to all information stored by the device, e.g. information on going to different supermarkets near their homes or other aspects of an autonomous life (interview, 1 May 2017). More precisely, some users reportedly expressed the wish to keep sufficient freedom of action and privacy without their relatives interfering. Accordingly, the interviewee repeatedly emphasised the feature that only registered users had access to the data collected by the assistive walker (interview, 1 May 2017). Subsequently, RT.Works seems to have abandoned the GPS function and wide collection of personal data for their subsequent model RT.2. There is merely the sensing function to detect the user’s movement

and the surface as well as the individual configuration of physical assistance, speed and braking (RT.Works n.y.). Although the collection and storage of personal data are frequently intended to enhance functionality for users, they are not always appreciated and may even become an obstacle to users' acceptance.

3.2.4 Financial and Regulatory Dimension

Users and developers alike mentioned the importance of device safety and the necessary certification of care robots' security as a crucial precondition for wide acceptance, official approval as healthcare or assistive devices and for the export of care robots and robotic care devices. In other words, both aspects influence the distribution of care robots and robotic care devices under the LTCI and onto the healthcare market. Therefore, the next section discusses the issue of financial and regulatory requirements as they were reported during the interviews in some more detail.

Financial promotion for care robots

Against the backdrop of the importance of LTCI, there is the need to pay particular attention to how far the robotic care devices are included in the reimbursement list. As the income of most aged people is limited, they rely heavily on the LTCI reimbursement system. For instance, users of the transfer assistance lift Tsurube B in private households do not have to bear the full costs for renting the device themselves. As the care manager and caregiving spouse explained, the users only had to make a co-payment of about 3,600 yen per month, as 80% of the rental fee was covered by long-term-care insurance in their case (on-site visit, 28 June 2017; Moritoh n.y.).

In comparison, the walking assistant robot RT.1 by Mobilika is not covered by the insurance, as it does not have the required U-shaped handles with a frame surrounding the user like conventional rollators. The representative of Mobilika stated that the RT.1 Assist Walker is therefore directed to customers with higher incomes who do not need reimbursement from their LTCI insurance (interview, 1 May 2017). Therefore, the usual customers for RT.1 were mainly people with savings, aged between 80 and 90. At the time of the interview, several dozen RT.1 Robot Assist Walkers had been sold in Chiba, Tochigi and Gunma Prefectures within two years. In some cases, two people shared one walking assistive robot, as more than one user can be registered. The original price for purchasing RT.1 in 2014 had been about 250,000 yen. It had fallen to about 230,000 yen at the time of the visit (interview, 1 May 2017). As for advertising the robot, Mobilika launched campaigns in newspapers, department

stores and at relevant exhibitions. The interviewee stated that care managers learned about new devices best at exhibitions. However, because they are often too occupied with nursing and caregiving duties, they do not have sufficient time to attend such events frequently (interview, 1 May 2017).

Meanwhile, RT.Works was able to place a subsequent model on the market, which is available at a price of about 120,000 yen. In contrast to the RT.1, the new model RT.2 meets the criteria of a U-shape handle grip, foldability and privacy concerns of users, place for a shopping bag and a seat for one person weighing up to 100 kg. Similarly, the RT.2 has sensing and braking functions that automatically support people walking uphill by slowly pulling them if necessary, and slowing down by employing brakes automatically when walking downhill (Mobilika 2017c). Consequently, the RT.2 has been accepted under the LTCI device list for reimbursement and can be rented for about 1,000 yen per month (interview, 1 May 2017; RT.Works n.y.). Whereas the interviewee mentioned that walking aids could be technically improved by employing more ICT and GPS technology, walking assistance devices with these functions were not covered by Japanese care insurance at the time of the interview (interview, 1 May 2017). GPS and ICT technology can lead to data security concerns. They might also be perceived as too technology-laden. It might have been for this reason why developers at RT.Works decided to withdraw the GPS and ICT function for RT.2.

We observed a similar development in the case of the transfer assistance and person carrier robot developed by Panasonic Age Free. The next generation of the robotic bed, which is named Reshone Plus, became included in the LTCI reimbursement list, because it was adapted to meet the specific criteria of the relevant device categories (interview, 12 July 2017; Panasonic n.y. (b)).

Safety requirements for the usage of care robots in Japan

While the healthcare market might be limited due to the LTCI fee list requirements and the disposable income of the target groups, the regulatory constraints can pose a far stricter hurdle to the commercialisation of healthcare products, as they regulate the approval of various devices regarding their safety, effectiveness and benefit to patients in Japan. The representative of the Robot Safety Center stated that, in principle, a care robot can be regarded as a medical or assistive device and standards for review by the centre are based on those for medicine or medical devices. As the interviewee added, the Japanese certifying authority PDMA (Pharmaceuticals and Medical Devices Agency) has some standards that apply to care robots as well, although their standards are not made specifically for robots

(interview, 24 March 2017). Nonetheless, the fact that most care robots might be combinations of the two categories of devices makes safety regulations difficult to apply in some cases (see Chapter 2.4 for further details).

Furthermore, many care robots developed in Japan are outside the scope of ISO standards or standards of other international certifying bodies such as the German TÜV, as they are recognised neither as medical devices nor as assistive technology. Therefore, various manufacturers in Japan refer to different standards at present. In response to this situation, the Robotic Safety Center decided to employ the ISO standards generally and developed its own additional test procedures and certification methods that could be applied for by manufacturers but are not mandatory in Japan (interview, 24 March 2017; Robot Safety Center n.y.). For instance, whereas Reshone can function as either bed or wheelchair, at the beginning it was not clear whether existing regulations for hospital-type beds or wheelchairs for long-term care would be met (interview, 24 March 2017). Nevertheless, the representative stated that Reshone would now meet the safety standards of robots in Japan as well as Panasonic's own safety standards. It has been recognised as a safe robot by ISO standard (ISO 13482:2014; METI 2014a, 2014b) as the first device in the category of personal carrier robots (interview, 12 July 2017; Panasonic n.y. (b)). Nevertheless, we still observe a need for further standardisation in the field of care robots and robotic care devices for homecare purposes. More precisely, the lack of standardisation represents a severe hurdle for successful commercialisation of newly developed care robots.

Supply and export

Some interviewees reported that there have been requests to export care robots from Japan. However, they explained that difficulties regarding safety regulations and certifications needed to be clarified (interviews, 24 March 2017 and 12 July 2017). Japanese manufacturers face the problem that there is no globally harmonised definition of "robot safety" (interview, 24 March 2017). Differing legal requirements pose a hurdle to exporting assistive devices to other countries such as the EU market. For instance, the robotic bed Reshone was developed at first for the Japanese market only (interview, 12 July 2017). One interviewee estimated that about 80% of care robot manufacturing companies in Japan mainly target domestic customers, because they do not want to bear the high costs for an ISO certification process (interview, 24 March 2017).

Similarly, there have been inquiries from potential customers from Asian countries as well as requests from Denmark, Germany and other countries expressing interest in purchasing

robotic care devices such as the wheelchair-bed Reshone or the assistive walker. Panasonic Age Free has the long-term goal to export Reshone. Therefore, the company has made efforts to receive the necessary CE mark required in the EU market (interview, 24 March 2017). Japanese companies need to acquire certifications under regional or international safety standards in the near future to be able to secure their markets abroad.

We can observe that the regulatory framework of safety standards and universal coverage of health insurance in Japans exerts a strong influence on the design of homecare technology, as devices have to meet regulatory and safety requirements to be approved for reimbursement under the LTCI scheme. Even though first and second generation devices did not meet the necessary criteria of the LTCI reimbursement list, developers in our two cases studies launched subsequent models that they had modified according to the required prerequisites and made them at the same time more cost-effective. This adaptation process forms a necessary condition for the successful diffusion within Japan. In addition, internationally harmonised standards are of high relevance, too, as they support the access to international markets.

Summary: Care Robots and Robotic Care Devices

Background
- ambiguity in the perception and definition of care robots
- a clear distinction between care robots and robotic care devices is missing in the Japanese language

Material Dimension
- objective: support for caregivers and recipients to reduce physical and psychological stress
- transfer lift Tsurube B: provides assistance for moving bedridden people from a bed into a wheelchair and is available under the LTCI fee list for rental but difficult in less spacious Japanese houses
- wheelchair-bed Reshone: provides a hybrid device for transfer and mobility to bedridden people in a homecare setting and requires less space than separate bed and wheelchair
- assist walker RT.1: provides mobility assistance by monitoring motion and controlling brakes, adjusting to the user's need

Social Dimension
- precondition: learning users' needs from experiencing care work in nursing/care facilities and private households
- added-value: robotic care devices reduce physical burden and mental stress of caregivers worrying about being able to carry out care work
- user feedback: users seem to prefer care robots that are easy to use, space-saving and do not resemble typical humanoid or animaloid robots with communication functions but are "appropriate" within the homecare setting (like a piece of furniture)

Financial and Regulatory Dimension
- globally harmonised standards for robot safety are lacking, which inhibits the export of care robots
- some robotic care devices do not yet meet the specific preconditions to be reimbursed under the LTCI (but the manufacturers introduced subsequent models accepted under the LTCI)
- various governmental subsidies and grants support the development and use of care robots

3.3 Monitoring Sensor Systems

This chapter presents the results of an interview and an on-site visit relating to monitoring sensor systems (*mimamori sensā*). The interview was conducted with a developer at Sekisui House, a company that employs sensor technology in their smart house solutions.

3.3.1 Background

Whereas the definition of the MHLW regarding assistive equipment remains rather narrow, the Joint Research Center (JRC) of the European Commission lists smart homes and generic information and communication technology (ICT) products, services and applications together with assistive technologies that are targeted to support the "independent living of aged people" (see Carretero 2015: 11 and Chapter 2.4). Accordingly, monitoring sensor systems in smart houses and other ICT-based appliances should be considered in the field of domestic healthcare technology. In Japan, "monitoring sensor systems for homecare purposes" (*zaitaku kaigo-gata mimamori shien kiki*) are one type of technology that employs "robot technologies with sensors and external communication functions to monitor elderly and other people in private homes" for the purposes of maintaining health and domestic healthcare (AIST n.y. (b)). According to the same source, monitoring systems might possess the following characteristics:

- Monitor multiple rooms at the same time.
- Be usable in bathrooms.
- Work in the dark.
- Not be solely dependent on care-receivers' voluntary actions for help (e.g., pressing a button or calling out for help).
- Not require the care-receiver to carry or wear a device with them.
- Send an alarm to the caregivers when the care-receiver falls.
- Send information about the care-receiver to the caregivers after detecting changes in indicators that are set by the manufacturer to monitor the daily life pattern or health of the care-receiver.
- Have the potential to provide a platform to monitor people with dementia through enhanced functions and additional devices and software.

Although such systems employ robot technology, we distinguish monitoring sensor systems from care robots and robotic care devices; because they are not devices equipped with a drive unit performing movements (see Chapter 3.2.1 for further details).

A number of Japanese manufacturers have made efforts to come up with sensor technologies and smart housing solutions specifically directed to elderly yet healthy residents.[11] Sekisui House is one of these and one of Japan's largest house building companies. It recently developed a Smart Healthcare House with a monitoring sensor system. Cowan and Turner-Smith (1999: 334) describe smart houses as follows:

> *'Smart Housing' is a term used to describe the electronic and computer-controlled integration of many of the devices within the home. […] It allows the integration of environmental controls for effective control of a building, either by deliberate control or automatically. This includes door and window openers, curtains and blinds, heating, lighting, security devices including motion sensors and video surveillance, telephone and communication, water taps, cooker, bed warming. Monitoring of activities can even be extended to daily health checks, for example an instrumented toilet has been developed to measure heart rate, temperature, and nutrition […].*

Located in Osaka, Sekisui House equipped their smart houses with sensor technology to regulate room climate and to monitor the vital data and daily activities of residents of these houses. The smart house project originated in the Home Energy Maintenance System (HEMS) produced by the company and intended to control electric power consumption within private houses (Sekisui House 2017; Nikkei 21 May 2015). The Smart Healthcare House clearly resembles the description of smart housing above, with its roots in an energy system that has been broadened to a new field of application.

3.3.2 Material Dimension

To elaborate on the important functions of the Smart Healthcare Houses, the interviewee referred to the large number of people who prefer to live at home until the end of their lives, along with the number of deaths from excessive heat and sudden deaths while taking a bath,

[11] For instance, the medical device corporation Nihon Kohden, located in Tokyo, has developed a monitoring system named Sukoyaka to offer a service of monitoring elderly residents (*kōreisha mimamori sābisu*) by automatically measuring their vital data at home. The system monitors users' daily activities and illumination and temperature inside the building, and is able to detect both accidents and illnesses of users by distinguishing between twenty different types of illnesses such as depression, lifestyle-related diseases or cancer (Nihon Kohden 2015; Nihon Kohden, n.y.). On the other hand, the business and home security company Secom, located in Tokyo and being one of the largest security service providers in Japan, offers an all-round safety service using sensor technology directed to one-person households of elderly people (Secom 2018).

which are particularly prevalent among the age group of 65 years or older in Japan (interview, 28 July 2017). More precisely, in 2013, 1,077 people died because of excessive natural heat (*netchūshō*) in Japan. Almost 80% of these were 65 years or older (65–79 years: 351 people, and 80 years or over: 482 people), of whom more than 85% died in their own homes. An investigation by the MHLW showed that 4,866 people died in 2014 through drowning in their bathtub at home suffering a "thermal shock" after entering the hot bath, compared to 2,870 people in 2004. In 2014, the age group of 75–84 years old was the largest (2,106), followed by those aged 85–94 (1,359) and those aged 65–74 (894) (MHLW 2015b). Most of these deaths by drowning occurred in winter because of excessive changes in temperature, but were not limited to this season. It is thought that the Japanese bathing style of immersing oneself up to the shoulders in hot water is one of the major causes of this type of death, particularly among elderly people (Consumers Affairs Agency 20 January 2016: 1–2). Sekisui House targeted this age group in particular with their Smart Healthcare House, as it is the group most affected by sudden death at home. Accordingly, the company intended to provide automatic functions to lower the likelihood of these accidents.

Picture 3.6: Patch-type sensor attached to the skin at the chest.

Picture 3.7: Screen with bio-information of smart house residents.

© Susanne Brucksch

Sekisui House's Smart Healthcare House employs two ways of sensing the bio-information of its residents and the living environment within the house, as the interviewee explained. One encompasses several sensors detecting information on the living environment and in-house activities from afar. The other device is a patch-type sensor that is attached directly onto the skin of the residents (see picture 3.6). This patch-type sensor records heartbeat, sleeping hours and other vital data. Based on the bio-information collected, the dialogue system displays details on the current state of health, as well as automatically generating

recommendations for health promotion and disease prevention, for example, on a screen in the living room or at other terminals (Sekisui House 2017; Nikkei 21 May 2015, see picture 3.7). The Sekisui House monitoring sensor system can clearly be classified as homecare technology alongside with several other health related functions.

3.3.3 Social Dimension

In this section, we document statements about the engineers' philosophy for developing a monitoring sensor system and various kinds of feedback reported by users.

Developing the Smart Healthcare House

The interviewee expressed the philosophy that smart houses have the ability to tackle important societal problems, such as global warming or healthy ageing. He stressed the role of private houses as a long-term investment for house buyers. That is, conceptualising houses as a material structure for a sustainable living environment often over generations and helping people to live healthily until the end of their lives (interview, 28 July 2017). In other words, we can clearly observe that Japan's fast-ageing society also prompted Sekisui House to invest in R&D activities targeting aged people and searching for solutions in the field of homecare technology.

The engineering team at Sekisui House developed a monitoring sensor system and patch-type sensor for their Smart Healthcare Houses without collaborating closely with researchers or other manufacturers. However, a medical expert at Nara Medical University assisted with the analysis and interpretation of the vital data collected from residents at the beginning of the project. The interviewee explained that medical expertise was required during the development process to assess the type and accuracy of the collected bio-information intended to indicate the health condition of residents (interview, 28 July 2017). To sum up, there are some challenges when it comes to sensor technology monitoring personal health data: the system provider has to guarantee reliability and accuracy during the detection of bio-information and for the automatically generated health recommendations.

Obtaining feedback on the Smart Healthcare House

The interviewee stressed that the development team at Sekisui House conducted a demonstration project of the monitoring sensor system (*kenkō mimamori jissho shiken*) in 2015 in Japan. A few hundred people participated in these experiments. The main target

group consisted of people in their sixties and seventies as potential residents of smart houses (interview, 28 July 2017). Participants “were able to get used to using the tablets better than we expected”, and “most participants seemed to enjoy using such digital devices” (interview, 28 July 2017). However, the interviewee also mentioned that experiments with the HEMS showed that the system led to a gradual loss of interest of residents after a short period. Users did not regularly pay attention to the information displayed. For that reason, Sekisui House added other content to the system, such as animated characters communicating with users to attract more attention (Sekisui House 2017; Nikkei 21 May 2015). Overall, the participants responded rather positively to the Smart Healthcare House during the demonstration project.

The engineers had to overcome several challenges during the development of their Smart Healthcare House. The company concluded after one year that they would put a halt to this pilot project despite such positive user feedback. The reasons were twofold: firstly, collecting vital data only during the daytime was not sufficiently effective to detect possible illnesses. The data did not reveal marked differences in the bio-information during daytime activities. The outcome could have been different, if vital data had been collected during daytime activities and sleeping periods and compared. Therefore, at the time of the interview, the development team at Sekisui House planned to extend data collection to night and sleeping time in the near future (interview, 28 July 2017).

Secondly, the development team received user complaints about some cases of rashes and discomfort caused by the patch-type sensor attached directly to the skin on their chest. For that reason, the company began to develop a contactless type of sensor that could detect bio-information of residents as precisely as the patch-type sensor (interview, 28 July 2017). The interviewee also reported on the development of sensor systems monitoring elderly people who increasingly live without contact to their neighbourhood. He also noted user concerns about data security, although he did not mention that any particular data security issues had occurred at Sekisui House. Potential buyers were also concerned about their privacy to be interfered with by family members, IT providers or healthcare services (interview, 28 July 2017). In other words, we encounter here issues similar to those in the field of care robots and robotic care devices. Hence, monitoring sensor systems have to find a balance between supporting an autonomous way of living at home while at the same time protecting the privacy and personal data of their users.

3.3.4 Financial and Regulatory Dimension

This section discusses the issue of financial and regulatory requirements as reported during

the interviews. The interviewee stated that deciding which bio-information could be utilised to indicate changing health condition and to generate automatic recommendations for the prevention of potential diseases was challenging (interview, 28 July 2017). Unless the accuracy and reliability of health data detection by the monitoring sensor system can be ensured, the user might lose interest in a smart health solution, or the corporation might even be held liable for consequences resulting from misleading health recommendations.

Several users responded that the automatic health recommendations were too general and, therefore, less useful in contributing to the detection or prevention of specific diseases. The interviewee explained that these expectations by smart house residents are undermined by the fact that Sekisui House as a manufacturing company is by law not allowed to offer too specific recommendations. Medical diagnosing and treatment in Japan are strictly regulated under the Medical Practitioners' Act (*ishi-hō*) (interview, 28 July 2017). The act states, "no person except a medical practitioner shall engage in medical practice" Chap. IV Art. 17 and "no medical practitioner shall provide medical care or issue a medical certificate or prescription without personally performing an examination" Chap. IV Art. 20 (Medical Practitioners' Act [1948] 2007). Consequently, the Smart Healthcare House offers a monitoring sensor system that makes either too vague recommendations, which are of little value, or too specific recommendations, which may result in liability cases or run into conflict with legal stipulations. Especially the regulatory constraint limits the possibility of valuable recommendations, and, consequently, the commercialisation of a wide spectrum of the domestic healthcare features integrated in smart houses.

Summary: Monitoring Sensor Systems

Background
- Sekisui House employed a monitoring sensor system in their Smart Healthcare House that originated in the Home Energy Maintenance System (HEMS) developed for their smart houses

Material Dimension
- vital data of users (e.g. heartbeat, breathing rhythm, sleeping hours and other bio-information) were collected with remote and patch-type sensors that were attached to the skin

Social Dimension
- philosophy: ageing and health topics could be addressed by smart house solutions
- medical expert at a Japanese university assisted with the analysis of the bio-information
- Sekisui House conducted a demonstration project in 2015 in Japan
- users found the use of tablets enjoyable
- issue: the patch-type sensor did not receive positive feedback but the company had plans to develop a contactless type of sensor

Financial and Regulatory Dimension
- discrepancy: recommendations cannot be too specific, since they may not substitute for a diagnosis by a medical professional, as this is strictly regulated under the Medical Practitioners' Act in Japan

3.4 ICT-based Telehealth Systems

In this section, we present findings from two interviews and on-site visits relating to ICT-based telehealth systems. Cowan and Turner-Smith (1999: 325) describe telehealth systems as one type of assistive technology relevant in the context of "reversal and amelioration of the declining capacities of older people". One of our case study involves the Fukui Medical Net in Fukui Prefecture. The other case concerns the so-called ism-Link network of Iida City and the neighbouring Shimoina District in Nagano Prefecture. Both networks link the homecare domain with the domain of institutional healthcare at community and prefectural level through information and communication technology (ICT). The two case studies offered a valuable opportunity to study the introduction of telehealth networks in the wider context of domestic and local healthcare in Japan including the acceptance and concerns of healthcare professionals, patients and their relatives.

Fukui Prefecture and Iida City are both located in peripheral regions of Japan, which can be characterised as being affected by particularly rapid ageing, declining populations and shortages of financial resources and workforce, particularly in medical and long-term care. The two cases are particularly worth examining, because they highlight the pivotal role of municipalities in the provision of healthcare and long-term care services (see Chapter 2.1 and 2.3 for further detail).

3.4.1 Background

The introduction of ICT-based telehealth systems is one measure implemented by local and prefectural governments in the context of "Regional Integrated Care Systems" (*chiiki hōkatsu kea shisutemu*), with support from the Ministry of Health, Labour and Welfare (MHLW; see Chapter 2.3 for further detail). Although the MHLW's definition of assistive equipment remains rather unspecific, the Joint Research Center (JRC) of the European Commission lists telehealth technologies together with other kinds of assistive technologies (see Carretero 2015: 11 and Chapter 2.4). More precisely, because *telehealth* covers the meaning of medical, long-term and domestic care, the term is most applicable in the context of ICT-based networks employed in regional care systems integrating medical and long-term care at a regional level in Japan. Subsequently, Carretero (2015: 11) defines telehealth as follows:

> *Telehealth or disease management applications deliver services from a healthcare provider to a citizen, from one health professional to another, or between citizens and family members (Stroetman et al., 2011). Telemedicine and telehealth are similar and in*

> *many documents appear as the same concept, but the former refers to services delivered by physicians only, and the latter to services provided by health professionals in general, including nurses, pharmacists, and others (WHO, 2009). In this framework of long-term care needs, home telehealth refers to a range of support, typically including not just clinical (medical) monitoring and intervention, but also a broader range of homecare support that more traditionally falls within the scope of social/homecare services (Empirica, WRC and European Commission, 2010).*

In contrast, the term *telemedicine* is still far more common than telehealth. Carretero (2015: 12) also points out the factor of geographical distance, which plays a crucial role in the implementation of such kinds of networks in peripheral regions. Therefore, we quote his definition of telemedicine as follows, as it is also more precise in terms of defining the technical particularities:

> *Telemedicine is defined by the WHO as "the delivery of healthcare services, where distance is a critical factor, by all healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of healthcare providers, all in the interests of advancing the health of individuals and their communities" (WHO, 1998). Telemedicine involves secure transmission of medical data and information, such as biological/physiological measurements, alerts, images, audio, video, or any other type of data needed for prevention, diagnosis, treatment and follow-up monitoring of patients (European Commission, 2009).*

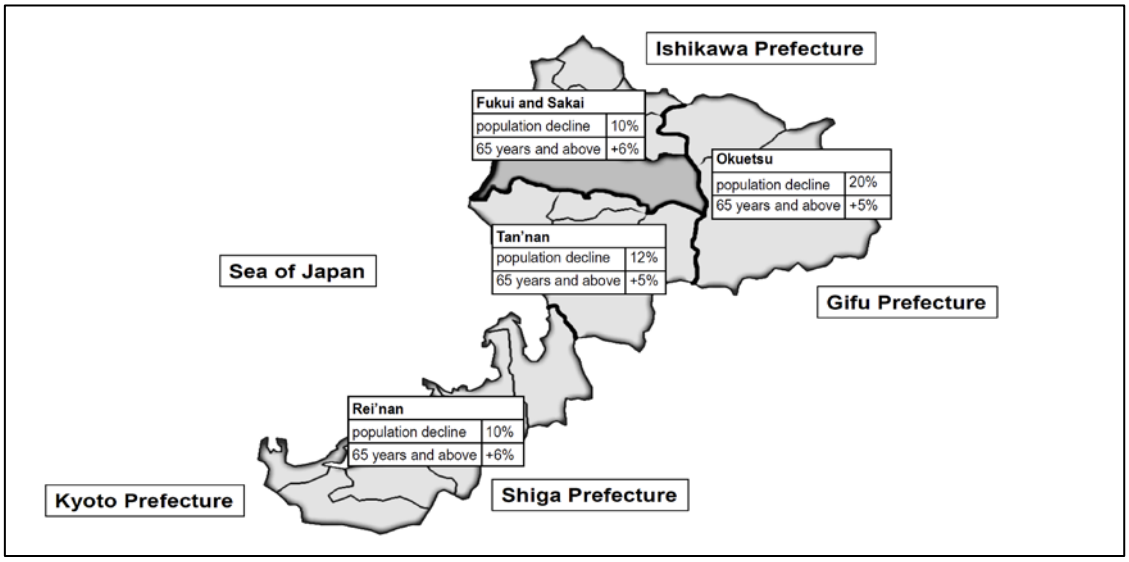
Consequently, we can understand by the term telemedicine particularly the linkage of institutions in the domain of medical care, including hospitals, clinics, rehabilitation centres and aftercare at home. For the sake of completeness, the term *telecare* should be mentioned, too. Telecare refers particularly to the domain of long-term and long-term care, and can be described as the "the provision of social care from a distance using telecommunications" (Carretero 2015: 12). Nevertheless, we decided to use the term ICT-based telehealth system for the Fukui Medical Net and Iida City's ism-Link, rather than the more frequently used terms of telemedicine and telecare. Moreover, we follow the meaning of the above-mentioned definition for the ICT-based networks examined, as they have already been broadened from the medical domain to that of long-term and domestic healthcare.

Fukui Prefecture

Fukui is a prefecture located on the Japan Sea with a coastline and mountainous areas close to the Japanese Alps, but not far from the major industrial centres of Osaka and Nagoya. Fukui Prefecture can be characterised as a peripheral region characterised by rapid ageing and population decline (see figure 3.1). For instance, two representatives of the prefectural government drew attention to a demographic development heading toward a peak of within 20 years, when about 23% of all inhabitants in Fukui Prefecture will be 75 years of age or older (interview, 27 April 2017b; see also Fukui Prefectural Government 2018a: 8). This coincides with the peak of aged people who will be certified for long-term care, about 10% of all inhabitants and about 23% of all people aged 65 years and above. Residents aged 75 and above are known to be most prone to fast-deteriorating physical conditions and therefore will most likely require a large amount of healthcare spending.

Fukui Prefecture has the highest number of working couples in Japan, which implies an obstacle when relying solely on domestic care conducted by spouses and relatives. This is why many elderly and other people with disabilities, long-term illnesses or physical conditions are frequently looked after in nursing homes and long-term care facilities. Nevertheless, the prefectural government intends to counteract this trend and to keep healthcare spending on such facilities low with its policy of "no new facilities" (*shinki zero*). In contrast, programmes to promote domestic healthcare have been expanded, such as the implementation of the Fukui Medical Net (interview, 27 April 2017b; see also Fukui Prefectural Government 2018a: 22, 41–42).

Figure 3.1: Demographic forecast for Fukui Prefecture (changes between 2015 and 2030)



Source: Based on data received during the interview (27 April 2017).

Iida City

Iida City and the Shimoina District with its 14 communities have 103,023 and 61,233 inhabitants respectively (see JGDC 2017).[12] In 2014, there were about 31,300 inhabitants in Iida City aged 65 and over, and 6,101 people registered for long-term care. We found 21 facilities targeted at aged people, with 586 professional staff employed. Even though no precise data were available regarding future demand, the municipal government of Iida City drew attention to the shortage of professional care workers, the growing financial burden and the planned increase in caregiving staff over the next few years. At present, 32% of the population in Iida City is aged 65 or over. The numbers of medical experts, nursing staff and care providers do not match the need for medical treatment and professional long-term care for the local population (Iida Municipal Government 2015: 1–2, 11, 33, 43–44). Moreover, there are only a limited number of hospitals, care facilities and care organisations, and they are mainly located in the city centre (interview, 24 July 2017). Iida City faces a particularly fast ageing and declining population similar to Fukui Prefecture and many other peripheral regions in Japan with detrimental consequences for the provision of care services and local fiscal conditions.

The representative of the municipal government explained that it is for this reason that Iida is searching for ways to support the local community and to sustain the municipal care systems (interview, 24 July 2017). As in other communities and regions, the local government of Iida City had been asked by the MHLW to implement a “Regional Integrated Care System” for medical and long-term care. Alongside other measures, the prefectural government launched the *ism-Link* project, an ICT-based system for telehealth services, to achieve the above-mentioned goal. Ism-Link interlinks health institutions and homecare services in Iida City and the neighbouring Shimoina District (interview, 24 July 2017). Located in the southern part of Nagano Prefecture within the Japanese Alps region, this area can be characterised as one with sharp contrasts between the urban centre of Iida City and the rural and mountainous areas of the surrounding district. The urban–rural divide implies different levels of access to healthcare services and homecare support for aged residents and requires different approaches to secure an adequate provision of medical and long-term care solutions.

[12] Shimoina District consists of 14 communities with their respective local administrative bodies. Precise data on healthcare infrastructure were not available. Therefore, we only present information provided by Iida City.

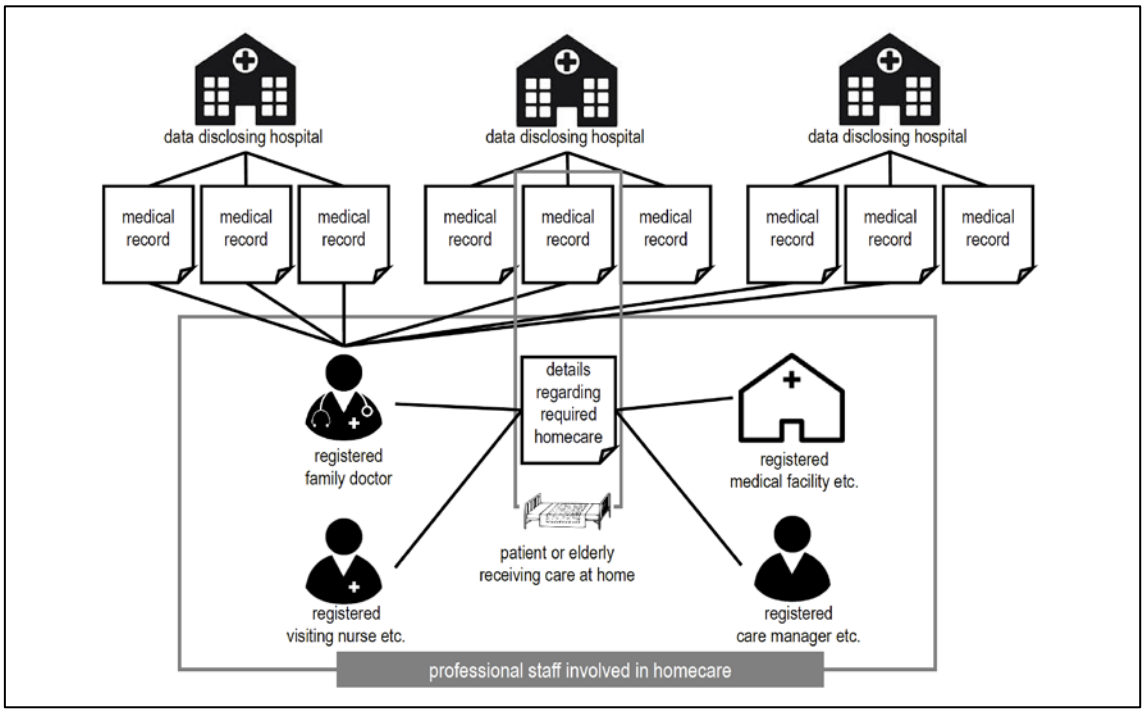
3.4.2 Material Dimension

Here we document information about the technical features and functionality of both ICT-based telehealth systems, namely the Fukui Medical Net in Fukui Prefecture and the ism-Link of Iida City.

Fukui Medical Net

The Fukui Medical Net was introduced in 2014, first at Red Cross hospitals, because of their large size and high number of patients (interviews, 27 April 2017a and 27 April 2017b). According to the interviewees, the reason that medical professionals together with the prefectural government of Fukui Prefecture decided to introduce the system was to differentiate clearly between and simultaneously interlink acute treatment at hospitals, on the one hand, and after- and long-term care at home provided by nursing or long-term care organisations, on the other (interview, 27 April 2017a).

Figure 3.2: Basic scheme of the Fukui Medical Net



Source: Based on information received during the interview (27 April 2017).

The Fukui Medical Net has been used for a variety of services, for instance, to share a patient's record and medical images, as well as for the exchange of information regarding a care recipient's daily life and health condition (interview, 27 April 2017b, see figure 3,2). As

for its interaction with other devices, access to health records within the telehealth network is only possible from terminals such as tablets or stationary computers that have been registered with the system and with a valid ID and password. As for security requirements, the interviewees explained that all patient records in the Fukui Medical Net are gathered in an autonomous data centre based on the highest data security technology available in Japan. According to the interviewees, there are also plans to enable data access on the move through various kinds of portable terminals in future (interview, 27 April 2017a; see also Fukui Iryō Jōhō Kanren Shisutemu Un'ei Kyōgikai n.y. (a), (b)). Furthermore, the representative of Fujitsu, the corporation providing the basic ICT infrastructure for the telehealth network, explained that Fukui Medical Net is based on SS-MIX2 (Standardised Structure Medical Information Exchange). The MHLW seems to have taken action to implement SS-MIX2 as the default standard for the storage of medical records in Japan (interview, 27 April 2017a; see also MHLW n.y. (b), Nikkei BP 2 February 2016). This would allow for the connection of different telehealth systems and exchange of health records between different regions of Japan.

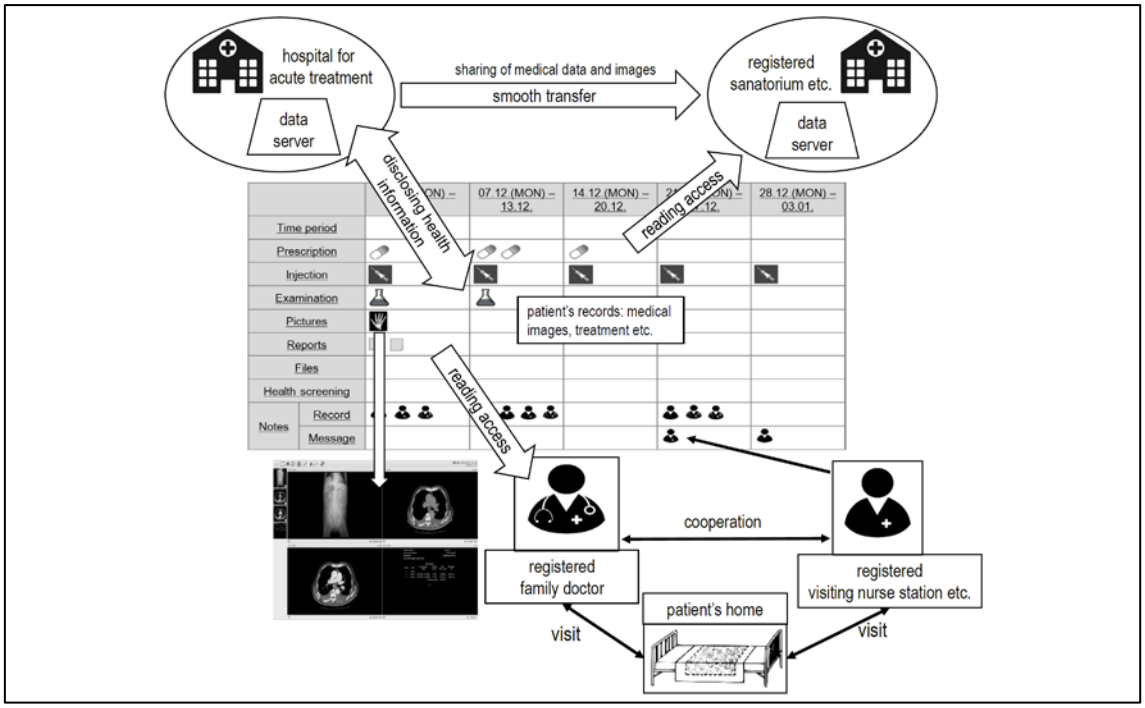
Before the introduction of the Fukui Medical Net, each hospital or healthcare institution managed their patients' records mainly by themselves (interview, 27 April 2017b). Consequently, medical practitioners, nursing staff and caregiving professionals did not have access to the patients' full health history; similar medical examinations might be conducted several times, and collaboration between different health institutions was limited. At present, about 280 private support centres, 80 mobile nursing stations, 280 care-manager stations, 270 insurance pharmacies and 560 medical institutions are registered to interlink with each other via the Fukui Medical Net. Among them, 19 hospitals were disclosing health information (*jōhō kaiji byōin*) to registered organisations in 2017, while other healthcare institutions were granted restricted access for browsing and reading such health records (*etsuran iryō kikan*).[13] Recently, day-care centres and nursing homes have also been encouraged to register with the telehealth system (interviews, 27 April 2017a and 2017b; see Fukui Iryō Jōhō Kanren Shisutemu Un'ei Kyōgikai n.y. (b), (c), (d)). Hence, the Fukui Medical Net increasingly allows various health institutions in the region to share a growing number of health records and even to bridge the institutional borders between the domains of medical care and long-term and domestic healthcare.

[13] The precise number of health institutions with reading permission was not given on the homepage of the Fukui Medical Net.

Ism-Link network of Iida City

The ism-Link network is a similar ICT-based telehealth system used to share health information among registered medical institutions, rehabilitation centres, sanatoriums, nursing homes, day-care centres, homecare organisations, family members treating patients and care recipients. For instance, health records stored within ism-Link contain information on patients' health history, medical examinations, blood test results, treatment records, medical images such as X-rays, CT or MRI scans and caregiving measures provided by healthcare professionals. Similarly, patient records can be accessed by registered health institutions with portable or stationary terminals such as PCs, laptops, or tablets through a secure pathway (interview, 24 July 2017; CaO 2016b: 6–7).

Figure 3.3: Basic scheme of the ism-Link network of Iida City and the Shimoina District



Source: Based on information received during the interview (24 July 2017 and IMH 2011).

According to the interviewee, the main purpose of the network was to link medical and long-term care institutions in Iida City and the Shimoina District and to strengthen the exchange of health information between them. Accordingly, the ism-Link was supposed to make the exchange of health records more efficient and faster by saving time for medical consultation and prescription of treatment between medical practitioners and caregiving professionals (interview, 24 July 2017). This connection implies the bridging of geographical distances between specialised hospitals located in the urban centre in Iida City and the provision of

professional care at home in more remote places. 16 hospitals disclosed health information (*jōhō kaiji byōin*) to other registered organisations, while 54 healthcare institutions were granted restricted access for browsing and reading health records (*etsuran iryō kikan*) in 2014 (IMH 2014, see figure 3.3 for further details). While 11,823 patients and 85 healthcare facilities participated in the ism-Link network in 2016, the number of participants has grown further to 16,512 residents and 179 facilities out of about 250 healthcare institutions in the region at the time of the interview. Most recently, a pharmacist association and a dentist association joined the network (interview, 24 July 2017; CaO 2016b: 6–7). In other words, about one tenth of the inhabitants of Iida City and the Shimoina District had joined the ICT-based telehealth network ism-Link by the time of the interview, and further increases can be expected.

3.4.3 Social Dimension

In this section, we explore the social dimension. We document the motivation for the implementation of the two telehealth networks, the partnerships to establish the complex ICT infrastructure and feedback, particularly from healthcare professionals, about the acceptance among patients and care recipients.

Fukui Medical Net

The representatives of Fukui Medical Net and the prefectural government of Fukui Prefecture reported that Fujitsu was chosen as partner to provide and develop a suitable ICT infrastructure for the envisioned telehealth system because the corporation provided the most compatible technology to meet the technical requirements. Fujitsu offered the only system available at that time that was able to display different types of health data and medical images stored on diverse terminals and screens of the various participating organisations (interview, 27 April 2017a). For this reason, the relationship between the steering committee of the telehealth network, the various healthcare institutions, the prefectural government and Fujitsu reached the level of a close collaboration including joint R&D activities.

However, the steering committee of the Fukui Medical Net also received complaints from participating healthcare organisations. According to the interviewees, some care workers expressed discontent about the administrative workload, as more time is required to input, store, update and exchange health information via the telehealth system (interview, 27 April

2017a). One of the interviewees expressed the opinion that medical, nursing and elderly-care professionals in the participating organisations could achieve an efficient level of literacy in using the Fukui Medical Net only if they used the telehealth system on a regular basis (interview, 27April 2017a). This shows, that some hurdles need to be overcome before the full scope of user acceptance and added value in terms of time efficiency can be achieved.

Ism-Link network of Iida City

The municipal government of Iida City purchased the ICT technology for its telehealth system from NEC, a corporation providing ICT network solutions, in 2009 (interview, 24 July 2017). Thereafter, the basic infrastructure of ism-Link was implemented to share health information between different organisations via the network. However, we did not observe a close collaboration between Iida City and NEC as in the case of the Fukui Medical Net. The relationship with NEC had the quality of a business partnership (interview, 24 July 2017).

Similar to the users of the Fukui Medical Net, some healthcare professionals reportedly expressed hesitation about using the ism-Link network pro-actively. One of the interviewees offered the explanation that older generations often stick to conventional means of communication that they are most used to, such as telephone and facsimile (interview, 24 July 2017). This again underlines the necessity of organising adequate training and ease of operation in order to raise acceptance among users and to achieve sufficient literacy in and regular use of the system.

3.4.4 Financial and Regulatory Dimension

This section highlights issues related to financial and regulatory requirements as reported during the interviews. Privacy and data security were mentioned in both case studies alike as a critical issue for gaining wide acceptance for telehealth networks. With the rise of ICT-based systems, questions of vulnerability, surveillance and control regarding such critical infrastructure automatically emerge.

Fukui Medical Net

Initially, the Fukui Medical Net was subsidised by the prefectural government. More specifically, Fukui prefecture provided a fund from tax revenues, which was used for investment in the necessary ICT infrastructure and the financing of terminals, such as

stationary computers or tablets, at the participating health institutions (interview, 27 April 2017b; see also Fukui Prefectural Government 2018b: 18)[14]. Whereas the running costs of the Fukui Medical Net were paid from membership fees of participating health institutions, amounting to 3,000–4,000 yen per month, it was intended to reduce the fees as much as possible in the near future (interview, 27 April 2017a). In contrast, all expenditures related to the healthcare of patients and long-term care recipients incurred in the context of the telehealth system were reimbursed under the national health or the long-term care insurance (interview, 27 April 2017A).

Regarding the regulatory constraints, there are different types of participating healthcare institutions with different permissions on data access and disclosure, which are specified by national laws and by their registration with the telehealth system as mentioned above (interview, 27 April 2017b). Every registered facility can access only such health information as has been determined by the occupational status of each healthcare professional and by related permissions (interview, 27 April 2017a). Patients have to give prior permission to each health institution or medical practitioner gaining access to their health records within the Fukui Medical Net (interview, 27 April 2017a). Surprisingly, the interviewees stated that there were barely any concerns from patients and care recipients. Only two patients out of several hundred thousand people had not allowed their health records to be exchanged via the telehealth system (interview, 27 April 2017a). This implies a high level of confidence among patients, care recipients and their relatives regarding privacy and data security in relation to the Fukui Medical Net.

Ism-Link network of Iida City

The MHLW strives to enable communities such as Iida City to implement regional systems for integrating medical and long-term care (see Chapter 2.3). Against this backdrop, the interviewees explained that this was one major reason why Iida City had received financial and administrative support from the central government and why it started to collaborate with

[14] Official numbers were not available for the Fukui Medical Net and Iida City's Ism-link network on how much financial support each received from the central government. Nevertheless, the MHLW has subsidised the introduction of ICT-based telehealth systems throughout Japan, for example, via the "Regional Medicine Revitalisation Fund" (*chiiki iryō zaisei kikin*) or the "General Securement of Domestic Medical and Long-Term Care Fund" (*zaitaku iryō kaigo sōgō kakuho kikin*) (e.g. MHLW 2012: 12, MHLW / Fujitsu 2017: 38–44). These financial resources came from tax revenues and were distributed to prefectural governments, which redistributed them among local communities after receiving applications.

neighbouring communities (interview, 24 July 2017). The municipal government of Iida City and the local administrative bodies of the neighbouring Shimoina District decided to finance the operation and maintenance of the ism-Link network fully through tax revenues. Registered health institutions and caregiving organisations were only required to pay internet charges to their local internet provider (interview, 24 July 2017; CaO 2016b: 6). In contrast to the Fukui Medical Net, there seem to be no further costs resulting from investment, operation or maintenance of the ism-Link network.

As in the case of the Fukui Medical Net, national laws in Japan specify which occupational group in a healthcare institution has permission to access what type of personal data, patient records or medical information. The ism-Link network is based on national guidelines on data security launched by the MHLW to secure technical requirements on data security in healthcare institutions (interview, 24 July 2017; see also MHLW 2017a). Again, each patient or care recipient has to grant prior permission regarding the storage and disclosure of his or her data within the ism-Link network and has the opportunity to withdraw the permission later if necessary. According to the interviewees, almost all patients agreed to participate in the ICT-based telehealth system (interview, 24 July 2017).

Summary: ICT-based Telehealth Systems

Background
- objective: increased shift of healthcare services from institutionalised care towards domestic healthcare
- purpose: to address rising healthcare spending and shortages of healthcare professionals in peripheral regions such as Iida City and Fukui Prefecture

Material dimension
- interlinking medical and long-term-care services by ICT-based telehealth technology, including the homecare context
- access possible from registered terminals
- concern: potential fragmentation of telehealth infrastructure among various regions in Japan

Social dimension
- precondition: linkage between public administration, ICT company, health institutions and MHLW
- decentralise implementation, management and maintenance to local or regional level
- issue: appropriate training among healthcare professionals is required to enhance literacy and efficiency

Financial and Regulatory Dimension
- initial investment for telehealth infrastructure and terminals mainly covered by subsidies from MHLW and the central government
- personal permission required for every health institution to feed in and access health data

4 Summary and Conclusion

The research project "Ageing in Japan: Domestic Healthcare Technologies" was launched, because the speed and intensity of Japan's demographic change, the innovative capacities of Japanese companies and the political priorities set by the Japanese government make Japan a leading case for exploring emerging solutions of domestic care technologies.

The research project comprised two parts. The first part analysed the Japanese demographic, fiscal and legal context relevant for the development and implementation of domestic care technologies. The second part consisted of case studies looking into the three most prevalent domestic care technologies in terms of stage of development and implementation. These were (1) care robots and robotic care devices, (2) monitoring sensor systems and (3) ICT-based telehealth systems. In the following, we summarise the main findings for each part.

Analysis of secondary sources confirm that the Japanese government puts high priority to the prevention or at least delay of elderly people's dependence on long-term care in order to tackle rapid ageing, lack of care workers and growing public expenditures. The triple challenges of providing and financing care and of securing qualified professionals are especially severe in Japan's peripheral regions.

The promotion of domestic healthcare through technical advances represents a central measure taken by the government to cope with these challenges. The Long-Term Care Insurance (LCTI), by which in principle all elderly residents in Japan are insured, defines categories according to which expenses for homecare solutions will be covered by the insurance. The system therefore sets important financing conditions and regulatory constraints for developers and manufacturers of domestic healthcare technologies. As insurers of long-term care, municipalities perform a central role in the provision of long-term care.

Our case studies were structured along the following dimensions and research questions:

- **Material Dimension:** *What kind of domestic healthcare technologies can be found in Japan? What stage of development or implementation can be observed?*
- **Social Dimension:** *What added value do domestic healthcare technologies generate from the perspective of users and developers?*
- **Financial and Regulatory Dimension:** *What financial and regulatory requirements do domestic healthcare technologies face?*

Material Dimension

The interviews showed that developers fully share the public goal to assist elderly and other people in Japan with disabilities, long-term illnesses or physical conditions to enable them to continue living in their homes into higher ages. Similarly, the expansion of domestic healthcare and health maintenance appears to decision-makers to be one promising measure among others to cap healthcare spending and tackle labour shortages by fostering technical homecare solutions. Another common goal in the field of care robots and monitoring sensor systems was to make long-term care more efficient in terms of financial and human resources. In other words, rising healthcare expenditures and shortages of professional care workers appear to be drivers for directing public and private R&D investment into the field of domestic healthcare technology.

The devices and systems developed for the homecare sector show a much higher variety than initially assumed. More precisely, Japan, being predominantly associated with entertaining robots, offers a far wider spectrum of assistive technologies in the field of domestic healthcare technologies. In the case of robotic care devices and monitoring sensor systems, the results showed that the perspectives of caregivers and care recipients were to a wide extent taken into account. We also found that several devices and systems had already achieved a high level of practicality in the context of daily healthcare practices, such as the assist walker RT.1, the transfer aid Reshone, and ICT-based telehealth systems in peripheral regions. To conclude, these examples suggest that Japan's rapid ageing, shortage of professional care workers and financial pressures are very likely to not only generate further R&D efforts, but also push the adaptation and diffusion of domestic healthcare technologies.

Social Dimension

Practicality is an enhancing factor, while the complexity of the device or system is an inhibiting factor with regard to the successful implementation of healthcare technologies. Training of target groups can at best partially resolve technical complexity. Although not all devices examined have yet been successfully implemented, developers gained wide experience through various experiments and trial rounds. Each development team utilised a network of healthcare facilities and private homes to gain practical experience of the homecare context and to obtain important feedback from users. Basically, safety, ease of use, saving space, security and privacy were crucial points expressed by target groups to developers of care robots and monitoring sensor systems. In particular, caregivers seem to

feel relieved by the help of transfer assistance aids, which free them from the mental stress and physical burden of lifting bedridden people. Moreover, care robots received more positive user feedback when they were not recognised as stereotypical robots but were designed as normal care equipment or furniture. Similarly, to the care robot cases, representatives of ICT-based telehealth systems reported that caregiving staff in particular showed hesitation to adopt newly established ICT-based telehealth networks. They drew attention to the need for appropriate training as a precondition for the successful adoption of the system. In general, busy care work leaves little room for dealing with too complex systems and appliances. In contrast, the monitoring sensor system was targeted at smart-house buyers with the idea of combining healthcare with enjoyable information features. However, more R&D is needed to increase the comfortableness of the sensors employed, and to achieve a sufficient level of accuracy and reliability in detecting bio-information.

Financial and Regulatory Dimension

Against the backdrop of an ageing population and rising healthcare costs, the Japanese government introduced measures to support the daily routine of elderly people through domestic services as well as emphasising health maintenance and preventive measures, namely care robots, monitoring sensor systems and ICT-based telehealth systems. Especially ICT-based telehealth systems were installed to sustain an adequate level of healthcare infrastructure in peripheral regions of Japan. All care robots discussed in this report received public financial support. However, the monitoring sensor system investigated received less governmental attention and, thus, less financial support in comparison to care robots. One major hurdle for successful commercialisation is the integration into national health and/or long-term-care insurance. For instance, the latter reimburses rental service fees or the purchase of homecare devices by up to 80 or even 90%. Whether a device is covered or not is based on criteria that range from safety, effectiveness and level of care.

Developers face high safety and security expectations from their caregiving and care-receiving users. They have to comply with strict standards to receive approval for their technology from authoritative bodies in Japan, if they enter the domain of healthcare. The categorisation as assistive devices or as medical devices may result in additional safety requirements. Regulations may also restrict the functionality of technical solutions. For instance, the monitoring sensor system of the Smart Healthcare House collecting bio-information faced regulatory constraints by the Medical Practitioners' Act, which prevented the system from generating more detailed health recommendations. Similarly, the robotic care devices possessed some monitoring feature, GPS function or units for collecting data

from their users. Here, the manufacturer responded to user concerns about privacy by limiting access to registered users, in the case of the robotic assistive walker RT.1, and a switch-off function, in the case of the subsequent model RT.2. The same aspect is prevalent in telehealth systems, which deal with sensitive data of their patients. They manage data security and privacy through limited access by strict user registration, patients' prior permission to feed in their records and different levels of access based on professional status and regulatory requirements.

In closing, we would like to emphasise that the results of these case studies can only offer preliminary and partial insights. Further research on health, technology, homecare appliances and telehealth in Japan is needed to grasp more fully the wide scope of activities and to keep pace with continuing new developments. Besides further empirical work, future research will also need to be complemented by more theoretical input from the social sciences and humanities to better conceptualise and analyse aspects of innovation governance, regulation, marketing of technology and user acceptance.

References

AIST (National Institute of Advanced Industrial Science and Technology, Japan). n.y. (a). *Kaigo robotto pōtaru saito* [Care Robot Portal Site]. http://robotcare.jp (accessed 15 February 2018).

AIST (National Institute of Advanced Industrial Science and Technology, Japan). n.y. (b). *Monitoring systems for private homes*. http://robotcare.jp/?page_id=1945&lang=en (accessed 21 May 2018).

ATA (The Association for Technical Aids). 2016. *Heisei 28-nendo. Kaigo robotto dōnyū kōji hyōshō jigyō* [2016 Public Award for Exemplary Businesses Using Care Robots with Good Practice]. http://kaigo-robotaward.jp/dl/2016guidebook.pdf (accessed 22 May 2018).

Campbell, J. C., 2014. "Japan's Long-Term Care Insurance Program as a Model for Middle-Income Nations". In: N. Ikegami (ed.): *Universal Health Coverage for Inclusive and Sustainable Development: Lessons from Japan*. Washington: World Bank Group, pp.57–67.

Campbell, J. C., Ikegami, N., and Tsugawa, Y. 2014. "The political-historical context of Japanese healthcare". In: N. Ikegami (ed.): *Universal Health Coverage for Inclusive and Sustainable Development: Lessons from Japan*. Washington: World Bank Group, pp.15–26.

Carretero, S. 2015. "Technology-enabled Services for Older People Living at Home Independently: Lessons for Public Long-term Care Authorities in the EU Member States.", In: *JRC Scientific and Technical Reports Series. Institute for Prospective Technological Studies*, Seville: European Commission, Joint Research Centre. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC96022/lfna27256enn.pdf (accessed: 30 November 2017).

CaO (Cabinet Office). 2012. *Kōreika no kenkō ni kansuru ishiki-chōsa* [Results of the Survey about Health Consciousness among Elderly People]. http://www8.cao.go.jp/kourei/ishiki/h24/sougou/gaiyo/pdf/kekka_1.pdf (accessed 4 December 2017).

CaO (Cabinet Office). 2014. *Kōreika no jōkyō* [Situation of Ageing]. http://www8.cao.go.jp/kourei/whitepaper/w-2016/zenbun/pdf/1s1s_1.pdf (accessed 29 March 2017).

CaO (Cabinet Office). 2016a. *Chi'iki no keizai 2016 – Jinkō genshō mondai no kokufuku* [Regional Economy 2016. For Overcoming the Challenges from Population Decline]. http://www5.cao.go.jp/j-j/cr/cr16/img/chr16_01-03-16z.html (accessed 4 December 2017).

CaO (Cabinet Office). 2016b. *Heisei 28-nendo seido, chihō gyōzai wākingu gurūpu. Shisatsu hōkokusho* [2016 Working Group on Systems and Local Financial Affairs. Report of Observations]. http://www5.cao.go.jp/keizai-shimon/kaigi/special/reform/wg3/280726/pdf/shiryou6.pdf (accessed 22 May 2018).

CaO (Cabinet Office). 2017. *Heisei 29-nenban kōrei shakai hakusho. Dai-isshō Kōrei-ka no jōkyō.* [White Paper on the Ageing Society 2017. 1. The Ageing Situation]. http://www8.cao.go.jp/kourei/whitepaper/w-2017/html/zenbun/s1_1_1.html (accessed 21 May 2018).

Consumers Affairs Agency [Shōhisha-chō] 2016/1/20. *News Release. Fuyuba ni tahatsu suru kōrei-sha no nyūyoku-chū no jiko ni o chūi kudasai!* [Please be careful concerning bathing accidents of elderly frequently occurring in winter!]

http://www.caa.go.jp/policies/policy/consumer_safety/release/pdf/160120kouhyou_2.pdf (accessed 12 March 2018).

Cowan, D. and Turner-Smith, A. (1999). “The Role of Assistive Technology in Alternative Models of Care for Older People (Appendix 4)”. In: Suderland (ed.): *With Respect to Old Age. Long-term Care – Rights and Responsibilities (Research Volume 2)*. London: HMSO, pp. 325–346.

DSSMI (Denshi Seifu no Sōgō Madoguchi Ī-gabu) [E-Government Service Portal E-Gov]. 2017. *Iyaku-hin, iryō-kiki nado no hin-shitsu, yūkōsei oyobi anzensei no kakuho nado ni kansuru hōritsu (Shōwa sanjūgo hōritsu dai-hyakuyonjūgo gō)* [Act to Secure the Quality, Effectiveness and Safety of Pharmaceuticals and Medical Devices (Year 1960, Law No. 145)] http://elaws.e-gov.go.jp/search/elawsSearch/elaws_search/lsg0500/detail?lawId=335AC0000000145#20 (accessed 12 March 2018).

EUR-Lex (EUR-Lex: Access to European Union Law). n.y. *Document 32017R0745.* http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2017.117.01.0001.01.ENG&toc=OJ:L:2017:117:TOC (accessed 12 March 2018).

Fukui Iryō Jōhō Kanren Shisutemu Un'ei Kyōgikai [Cooperative Medical Information System Management Council]. n.y. (a). *Fukui iryō jōhō kanren shisutemu un'ei kyōgikai kaisoku* [Regulations of the Cooperative Medical Information System Management Council]. http://www.fukui.med.or.jp/fukuimedical-net/iryou/file/kyogikai_kaisoku2018.pdf (accessed 22 May 2018).

Fukui Iryō Jōhō Kanren Shisutemu Un'ei Kyōgikai [Cooperative Medical Information System Management Council]. n.y. (b). *Iryō kiki-muke* [For Health Institutions]. http://www.fukui.med.or.jp/fukuimedical-net/iryou/index.html#participation (accessed 22 May 2018).

Fukui Iryō Jōhō Kanren Shisutemu Un'ei Kyōgikai [Cooperative Medical Information System Management Council]. n.y. (c). *Soshiki* [Organisation]. http://www.fukui.med.or.jp/fukuimedical-net/about/index.html (accessed 22 May 2018).

Fukui Iryō Jōhō Kanren Shisutemu Un'ei Kyōgikai [Cooperative Medical Information System Management Council]. n.y. (d). Kenmin-muke [For Citizens of the Prefecture]. http://www.fukui.med.or.jp/fukuimedical-net/kenmin/index.html (accessed 22 May 2018).

Fukui Prefectural Government (*Fukui-ken Kengyōsei*). 2018a. *Fukui-ken rōjin fukushi keikaku. Fukui-ken kaigo hoken jigyō shien keikaku* [Fukui Prefecture's Welfare Plan for the Elderly. The Care Insurance Services Support Plan in Fukui Prefecture]. http://www.pref.fukui.lg.jp/doc/kourei/dai7ki-kaigokeikaku_d/fil/dai7ki-kaigokeikaku.pdf (accessed 21 May 2018).

Fukui Prefectural Government (*Fukui-ken Kengyōsei*). 2018b. *Heisei 30-nendo tōsho yosan* [Initial Budget of the Year 2018]. http://www.pref.fukui.jp/doc/zaisei/fukuikenyosan/tousyo30_d/fil/002.pdf (accessed 22 May 2018).

Good Design Award. n.y. *Award-winning Item. Walking Assist Robot.* [Robotics Assisted Walker RT.2]. http://www.g-mark.org/award/describe/45396 (accessed 22 May 2018).

Iida Municipal Government (Iida Shisei). 2015. *Kōreisha fukushi keikaku, kaigo hoken jigyō shien keikaku* [Welfare Plan for the Elderly. The Care Insurance Services Support Plan]. https://www.city.iida.lg.jp/uploaded/attachment/21610.pdf (accessed 21 May 2018).

Ikegami, N. (ed.) 2014. *Universal Health Coverage for Inclusive and Sustainable Development: Lessons from Japan*. Washington: World Bank Group.

IMDRF (International Medical Device Regulators Forum). n.y. *GHTF/SG1/N071:2012. Final Document*. http://www.imdrf.org/docs/ghtf/final/sg1/technical-docs/ghtf-sg1-n071-2012-definition-of-terms-120516.docx (accessed 12 March 2018).

IMDRF/GHTF (International Medical Device Regulators Forum / Global Harmonization Task Force on Medical Devices). 2012. *International Medical Device Regulators Forum*. http://www.imdrf.org (accessed 12 March 2018).

IMH (Iida Municipal Hospital). 2011. *Iida Shimoina. Shinryō jōhō renkei shisutemu (ism-Link)* [The Cooperative Medical Examination and Information System (ism-Link)]. 7 December. http://www.imh.jp/wp-content/uploads/e35c9555eaf16b1709ff8967c9211a87.pdf (accessed 22 May 2018).

IMH (Iida Municipal Hospital). 2014. *Iida Shimoina. Shinryō jōhō renkei shisutemu (ism-Link) no go-an'nai* [Explanation of the Cooperative Medical Examination and Information System (ism-Link)]. http://www.imh.jp/040-d/local/p8380/ (accessed 22 May 2018).

Interview with a representative from the Robotic Safety Center, March 24, 2017.

Interview with representatives of Fukui Medical Association, of Fujitsu (Healthcare Systems) and of Fukui Prefecture, April 27, 2017a.

Interview with representatives of the Healthcare and Welfare Unit of Fukui Prefecture, April 27, 2017b.

Interview with a representative from Mobilika, May 1, 2017.

Interview with users of the lift Tsurube B manufactured by Moritoh Corporation, June 28, 2017.

Interview with a representative from Panasonic (Age-Free Business Unit), July 12, 2017.

Interview with representatives from the Iida City, July, 24, 2017.

Interview with a representative from Sekisui House, July 28. 2017.

ISO (International Standard Organization). 2014. *Robots and robotic devices. Safety requirements for personal care robots. ISO 13482:2014(en)*. https://www.iso.org/obp/ui/#iso:std:iso:13482:ed-1:v1:en (accessed 21 May 2018).

JGDC (Japan Geographic Data Center). 2017. *Heisei 24-nen 4-gatsu chōsa. Shichōson-betsu. Jinkō, setai-sū* [Survey on Population and number of households separated according to communities. April 2017]. http://www.kokudo.or.jp/service/data/map/nagano.pdf (accessed 21 May 2018).

Matanle, P. and Rausch, A. (eds.) (2011). *Japan's Shrinking Regions in the 21st Century: Contemporary Responses to Depopulation and Socioeconomic Decline*. Amherst, N.Y.: Cambria Press.

MEDDEV (Medical Device Vigilance System). 2010. *MEDICAL DEVICES: Guidance document. In Classification of Medical Devices, June 2010, 2. 4/1 Rev. 9*. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwilmsvyrY7bAhUGv7wKHfIMCUgQFggtMAA&url=http%3A%2F%2Fec.europa.eu%2FDocsRoom%2Fdocuments%2F10337%2Fattachments%2F1%2Ftranslations%2Fen%2Frenditions%2Fnative&usg=AOvVaw2MLK9lr2lQcxfjMxk4SPyr (accessed 18 May 2018).

Medical Practitioners' Act (Ishi-hō). 2007. *Shōwa nijūsan-nen shichi-gatsu sanjūnichi hōritsu dainihyaku ichigō* [Act No. 201 of July 30, 1948]. http://www.japaneselawtranslation.go.jp/law/detail/?id=2074&vm=04&re=02 (accessed 22 May 2018).

METI (Ministry of Economy, Trade and Industry). 2014a. *Global Safety Standard ISO13482 was Issued for Service Robots*. http://www.meti.go.jp/english/press/2014/0205_01.html (accessed 21 May 2018).

METI (Ministry of Economy, Trade and Industry). 2014b. *Japanese Service Robots were Certified under Global Safety Standard ISO13482 for the First Time in the World* http://www.meti.go.jp/english/press/2014/0217_03.html (accessed 21 May 2018).

MHLW (Ministry of Health, Labor and Welfare). 2002. *Direction of Health and Welfare Policies for the Elderly over the Next Five Years.* http://www.mhlw.go.jp/english/topics/elderly/care/6.html (accessed 1 February 2018).

MHLW (Ministry of Health, Labor and Welfare). 2009. *Yōgo no teigi* [Definitions of Terms Used]. http://www.mhlw.go.jp/toukei/saikin/hw/kaigo/service09/dl/yougoteigi.pdf (accessed 30 November 2017).

MHLW (Ministry of Health, Labor and Welfare). 2011. *Definitions*. http://www.mhlw.go.jp/english/database/db-hss/dl/siel-2011-04.pdf (accessed 30 November 2017).

MHLW (Ministry of Health, Labor and Welfare). 2012. *Heisei 24-nendo Kōsei Rōdō kagaku tokubetsu kenkyū jigyō. Zaitaku iryō kaigo renkei wo susumeru tame no jōhōkyōyū to ICT katsuyō* [Special Research Project by the MHLW in 2012. Information Sharing and ICT Use to Push Forward Care Cooperation]. http://www.mhlw.go.jp/file/06-Seisakujouhou-12400000-Hokenkyoku/0000119320.pdf (accessed 21 May 2018).

MHLW (Ministry of Health, Labor and Welfare). 2014a. *Kaigo jinzai no kakuho ni tsuite. Dai ikkai fukushi jinzai kakuho taisaku kenshō-kai (H26.6.4), shiryō 2* [Securing Human Resources in Long-term Care. First Meeting about Measures to Secure Human Resources in the Field of Welfare (June 4, 2014), Sources 2]. http://www.mhlw.go.jp/file/05-Shingikai-12201000-Shakaiengokyokushougaihokenfukushibu-Kikakuka/0000047617.pdf (accessed 29 January 2018).

MHLW (Ministry of Health, Labor and Welfare). 2014b. *Jinkō dōtai chōsa 2013-nen. Shibō no basho-betsu ni mita nenji-betsu shibō-sū* [Vital Statistics 2013. Annual Mortality by Place of Death]. E-Stat. http://www.e-stat.go.jp/SG1/estat/List.do?lid=000001108740 (accessed 29 March 2017).

MHLW (Ministry of Health, Labor and Welfare). 2015a. *2015-nen ni muketa kaigo jinzai ni kakaru jukyū suikei (kakutei-chi)* [Demand and Supply of Care Personnel until 2025 (Definitive Value)]. http://www.mhlw.go.jp/stf/houdou/0000088998.html (accessed 1 February 2018).

MHLW (Ministry of Health, Labour and Welfare). 2015b. *Kōsei Rōdōshō Daijin Kanbō Tōkei Jōhō-bu "Heisei 27-nendo wagakuni no jinkō dōtai – Heisei 25-nen made no dōkō –" (Heisei 27 2-gatsu 25-nichi hakkō) yori bassui)* [Summary by the Ministry of Health, Labour and Welfare, Statistics and Information Department of the Minister's Secretariat "Our Country's Population Development in 2015 – Trends until 2013" (Published on February 25, 2015)]. http://www.mhlw.go.jp/file/06-Seisakujouhou-10900000-Kenkoukyoku/necchusho25_1.pdf (accessed 21 May 2018).

MHLW (Ministry of Health, Labor and Welfare). 2015c. *Kōteki kaigo hoken seido no genjō to kongo no yakuwari* [Present Situation and Future Role of the Public Care Insurance System]. http://www.mhlw.go.jp/file/06-Seisakujouhou-12300000-Roukenkyoku/201602kaigohokenntoha_2.pdf (accessed 1 February 2018).

MHLW (Ministry of Health and Welfare Labour). 2016a. *2016-nen 6-gatsu 3-nichi. Dai-59-kai shakai hoshō shingikai kaigo hoken bukai gijiroku* [Minutes of 59th Meeting of Health

Insurance Committee, Social Security Council, June 3, 2016] http://www.mhlw.go.jp/stf/shingi2/0000133856.html (accessed 22 May 2018).

MHLW (Ministry of Health and Welfare Labour). 2016b. *Long-Term Care Insurance System of Japan*. http://www.mhlw.go.jp/english/policy/care-welfare/care-welfare-elderly/dl/ltcisj_e.pdf (accessed 28 December 2017).

MHLW (Ministry of Health, Labour and Welfare). 2017a. *Iryō jōhō shisutemu no anzen kanri ni kansuru gaidorain (Heisei 29 5-gatsu)* [Guidelines for the Safety Management of the Medical Information System (May 2017)]. http://www.mhlw.go.jp/stf/shingi2/0000166275.html (accessed 21 May 2018).

MHLW (Ministry of Health and Welfare Labour). 2017b. *Heisei-28-nen. Kokumin seikatsu kiso chōsa* [Basic survey of Japanese people's lifestyles 2016]. http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa16/dl/16.pdf (accessed 21 May 2018).

MHLW (Ministry of Health, Labor and Welfare). n.y. (a). *Establishing 'the Community-based Integrated Care System'*. http://www.mhlw.go.jp/english/policy/care-welfare/care-welfare-elderly/dl/establish_e.pdf (accessed 1 February 2018).

MHLW (Ministry of Health, Labor and Welfare). n.y. (b). *Iryō bunya no jōhō-ka no suishin ni tsuite* [About the Progress of Informatization in the Medical Field]. http://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kenkou_iryou/iryou/johoka/index.html (accessed 21 May 2018).

MHLW / Fujitsu (Ministry of Health, Labour and Welfare / Fujitsu Corporation). 2017. *Chi'iki ni okeru iryō, kaigo renkei kyōka ni kansuru chōsa kenkyū (Chi'iki hōkatsu kea shisutemu kōchiku ni kan suru ICT katsuyō no arikata)* [Surveys and Research about Increasing Regional Cooperation Regarding Medical Treatment and Care Cooperation. (How ICT Use Should be in Regard to the Structure of the Community-based Integrated Care System)]. http://www.mhlw.go.jp/file/06-Seisakujouhou-12400000-Hokenkyoku/0000161932.pdf (accessed 21 May 2018).

Mobilika. 2017a. *Hokō ashisuto robotto RT.1* [The Walking Assist Robot RT.1].

Mobilika. 2017b. *Shin-tōjō! Robotto ashisuto uōkâ RT.2* [Now Available! The Walking Assist Robot RT.2].

Mobilika. 2017c. *Zutto genki ni arukitai!* [I Want to Continue to Walk Actively!].

MOF (Ministry of Finance, Japan). 2016. [Sources about Japanese Financial Affairs]. http://www.mof.go.jp/budget/fiscal_condition/related_data/201610.html (accessed 2 March 2017).

Moritoh, n.y. *Product Information. Beddo-yō lifuto. Tsurubē shirīzu B setto* [Product Information. Lift for (Lifting People Out of) Bed. Tsurube Series B-Set]. http://www.moritoh.co.jp/products/tsurube-b/ (accessed 22 May 2018).

Nihon Kohden. 2015. *Puresu rirīsu 2015-nen* [Press Release 2015]. http://www.nihonkohden.co.jp/news/15031801.html (accessed 15 February 2018).

Nihon Kohden, n.y. *Sukoyaka*. https://www.sukoyaka.ne.jp/news/pdf/HLW_201511.pdf (accessed 1 March 2018).

Nikkei (Nihon Keizai Shinbun). 2015/5/21. *Kuchō mo kenkō mo kanri. Sekisui ga jisedai sumāto hausu* [Sekisui (Introduces) Next Generation Smart House (that) Monitors Health and Climate]. https://www.nikkei.com/article/DGXMZO86942550Y5A510C1000000/ (accessed 15 February 2018).

Nikkei BP (Nikkei Business Publications) 2016/2/22. *SS-MIX/SS-MIX2 to wa* [What is the SS-MIX/SS-MIX2]. http://tech.nikkeibp.co.jp/dm/atcl/word/15/327920/021900010/?ST=health (accessed 22 May 2018).

OECD (Organisation for Economic Co-operation and Development). 2018a. *Data: Elderly Population*. https://data.oecd.org/pop/elderly-population.htm (accessed 22 January 2018).

Panasonic. n.y. (a). *Kaigo yōhin, setsubi* [Care Articles and Equipment]. https://sumai.panasonic.jp/agefree/products/ (accessed 22 May 2018).

Panasonic. n.y. (b). *Rishō ashisuto robotto rishōne Plus* [The Assistance Robot Reshone Plus for (Helping Elderly People) to Get Up]. http://sumai.panasonic.jp/agefree/products/resyoneplus/specs.html (accessed 22 May 2018).

Panasonic. n.y. (c). *Rishōne Plus dōnyū jirei* [Example of Reshone Plus in Use]. http://sumai.panasonic.jp/agefree/products/resyoneplus/jirei/home01.html (accessed 22 May 2018).

Robertson, J. (2017). *Robo sapiens japanicus: Robots, Gender, Family, and the Japanese Nation*. Oakland: University of California Press.

Robot Award n.y. *Saiyūshū chūshō, benchâ kigyō-shō (chūshō kigyō chōchō kanshō)* [Award for the Best Small, Medium and Venture Enterprises (*Small* and Medium *Enterprise Agency Director*-General's *Award*)]. http://www.robotaward.jp/winning/7th%20Robot-GBsingle07.pdf (accessed 22 May 2018).

Robot Safety Center (Seikatsu Shien Robotto Anzen Kenshō Sentā). n.y. *HOME. Seikatsu shien robotto anzen kenshō sentā* [Home. The Robot Safety Center for Testing (Everyday) Life Support Robots]. http://robotsafety.jp/wordpress/ (accessed 21 May 2018).

RT.Works n.y. *Robot Assist Walker RT.2*. https://www.rtworks.co.jp/eng/product/rt2.html (accessed 22 May 2018).

Secom. 2018. *Kōrei-ka mimamori sābisu* [Protecting Sensors for Elderly People]. https://www.secom.co.jp/homesecurity/plan/seniorparents/?link=kv (accessed 15 February 2018).

Sekisui House. 2017. *Katsudō 1: "Netto. Zero. Enerugī. Hausu" o kakudai* [Activity 1: Expanding on "Houses with Internet and Zero Energy (Consumption)"]. https://www.sekisuihouse.co.jp/sustainable/netzero/objective1_7/index.html (accessed 15 February 2018).

SME Agency (Small and Medium Enterprise Agency). 2014. *2014 White Paper on Small and Medium Enterprises in Japan. Fight Song for Micro Businesses*. http://www.chusho.meti.go.jp/pamflet/hakusyo/H26/download/2014hakusho_eng.pdf (accessed 18 December 2017).

Sone, Y. 2017. *Japanese Robot Culture: Performance, Imagination, and Modernity*. New York: Palgrave Macmillan.

Tokyo Metropolitan Government (Tokyo Metropolitan Government Bureau of Social Welfare and Public Health). 2016. *Heisei 27-nendo, Kōreika shisaku ni kansuru tomin ishiki chōsa chōsa kekka (gaiyō-han)* [Results of the 2015 Survey about Population Awareness Regarding Measures for the Ageing Society (Overview), October 2016]. http://www.metro.tokyo.jp/tosei/hodohappyo/press/2016/10/27/documents/20.pdf (accessed 30 January 2018).

Wagner, C. 2010. "'Tele-Altenpflege' und 'Robotertherapie': Leben mit Robotern als Vision und Realität für die alternde Gesellschaft Japans" ["Telecare for the Elderly" and "Robot

Therapy": Living with Robots as Vision and Reality for Japan's Ageing Society]. *Japanstudien [Japan Studies]*, 21(1), pp. 271-298, DOI: 10.1080/09386491.2010.11826998 (accessed 12 March 2018).

Wagner, C. 2013. *Robotopia Nipponica. Recherchen zur Akzeptanz von Robotern in Japan* [Robotopia Nipponica. An Investigation about the Acceptance of Robots in Japan]. Baden-Baden, Germany: Tectum Publishers.

WHO Centre for Health Development. 2004. *A Glossary of Terms for Community Healthcare and Services of Older Persons. WTO Ageing and Health Technical Report Vol. 5*. http://www.who.int/kobe_centre/ageing/ahp_vol5_glossary.pdf (accessed 30 November 2017).

Zenshukyo (Zenkoku Chūshō Kigyō Torihiki Shinkō Kyōkai) [National Association of Trade Promotion for Small and Medium Enterprises]). 2015. *Kō-eki zai-dan hō-jin. Zenkoku Chūshō Kigyō Torihiki Shinkō Kyōkai* [The National Association of Trade Promotion for Small and Medium Enterprises. A Public Interest Incorporated Foundation]. http://www.zenkyo.or.jp/index.htm (accessed 1 February 2018).

ZFSSK (Zenkoku Fukushi Yōgu Senmon Sōdan Inkyōkai) [Japanese Advisory Committee for Assistive Devices]. n.y. *Kaigo hoken to fukushi yōg*u [Care Insurance and Medical Devices]. http://www.zfssk.com/kaigo/index.html (accessed 1 February 2018).