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Human Assistant Robotics in Japan

- Challenges and Opportunities for European Companies-

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1 Executive Summary

In 2007, Japan had reached the state of a hyper-aged society and people aged 65 years and older represented at least 21% of the population. Today demographic projections even predict a further rise to 40% by 2060. Having resulted both in a severe shortage of nursing personnel and an increasing demand of care, Japan's ageing population is now accelerating the development and implementation of human assistant robots.

Since Japan is leading in developing advanced robot technologies, the government has pushed forward its “Industrial Revolution driven by Robots” or “Robot Revolution” in order to showcase a society in which assistant robots are common. Meanwhile the market for such robots is growing, showing an increasing potential over the coming decades.

Typical types of human assistant robots are mobile servant robots, physical assistant robots, person carrier robots, robots for monitoring and for companionship. All of them are expected to rise significantly in sales worldwide. In Japan nursing care robots are predicted to grow the fastest among service robots expecting a market growth from JPY 16.7 billion to JPY 404.3 billion (2015 to 2035).

The report offers an overview of the Japanese human assistant robotics market including the analysis of influencing factors and societal trends, a portrait of the market environment, as well as the discussion of opportunities and challenges for the European companies.

2 Methodology

The report is built on data and information sourced from primary[1] and secondary research. It considers various English-language sources, as well as a few Japanese-language sources that were mainly gathered via Internet research.

2.1 Information on general economic and political activities

First, to conduct a more detailed analysis of the market several European and Japanese bodies were contacted in order to gather basic information on the market's current status and the number of players. The questions asked involved an estimation of 1. Domestic companies operating in assistant robotics, 2. Domestic companies with a branch in Japan operating in assistant robotics and 3. Additional contact data. Further questioning included specific information about domestic policy strategies for the implementation of robotics into the healthcare sector.

To start with, European embassies and chambers of commerce in Japan, as well as business support organisations were addressed. Secondly, especially in regard to country-specific robot strategies, the focus was shifted to political bodies and affiliated organisations. This included European entities such as the European Commission and its national contact points. In addition, contact was made with robotics expert networks, associations affiliated with healthcare industry, technology institutes, project clusters, robotics platforms and associations for assistive technologies. In total, 260 entities in 26 countries (including Japan) were contacted.

100 out of those 260 contacts responded. 57 contacts held relevant information, however 43 could not provide data due to a lack of research, forwarded the inquiry or did not know of such information at all.

[1]Interviews, a survey andvisits to exhibitions

2.2 Surveyed companies and research facilities

To gather insight information on the Japanese and European market for human assistant robotics, a questionnaire was prepared to be sent to relevant companies and research facilities based in Japan and in different European countries. For this purpose, manufacturers, distributors, assistant robotics-related service providers, software and hardware producers, as well as component suppliers were selected as the industrial target group. Research facilities and centres cooperating with the industry and/ or being involved with European research or cluster projects in the field of human assistant robotics were selected as the main target group in academia, complemented by several laboratories belonging to prestigious Japanese universities.

2.2.1 Main content of the questionnaire

The questionnaire took into account the interviewees' respective characteristics and mainly consisted of up to 12 question sets regarding a general market assessment, their product(s), customer and user target groups, competition, technology and components, research and cooperation, financing, the regulatory framework, foreign markets and import and export.

On the Japanese side 44 companies (mainly manufacturers of robotics systems) were identified and contacted out of which 6 declined for different reasons and only 6 participated in the survey (13.6%). Other companies did not respond at all or stopped responding. Out of the 26 contacted Japanese research facilities only 1 was willing to be surveyed (3.8%), whereas the rest did not provide any response to the inquiries.

On the EU side the outcome was only slightly better. In total, 49 companies could be identified and contacted (mainly manufacturers and distributors) out of which 4 declined and 8 took part in the survey (16.3%). The participation rate among research facilities amounted to 7% with 3 out of 21 contacted institutions willing to answer the questionnaire. One facility declined and 17 did not respond at all.

As defined by the European Commission[2], 33% of the Japanese companies questioned can be categorized as SMEs employing less than 250 staff members and having an annual turnover of less than EUR 10 million. One company can be classified as micro enterprise that employs fewer than 10 staff members and whose annual turnover does not exceed EUR 2 million. The remaining 3 companies are large companies with at least 850 staff members. In regard to the European companies, 3 out of 8 are micro enterprises, 2 are SMEs and 3 cannot be further categorized due to missing data on staff headcount and turnovers (although they are most likely to be classified as SMEs).

2.3 Annotation

Up to this moment the research could not reveal exact information and data on the approximate total number of Japanese and European companies operating on the market of human assistant robotics. Since it is more than likely that this number by far exceeds the current contacted companies, not to mention the very low participation rates of both industry and academia, it should be pointed out that the information gathered from this survey cannot be considered representative. However, it can be used to shed some light on certain aspects and thus will be presented in the following paper.

2.4 Area of observation and definition of "human assistant robotics"

One of the main problems that had to be faced right from the beginning was the definition of the term "human assistant robot" (hereafter also referred to as "assistant robot", "personal assistive robot", "nursing care robot", "impairment assistance robot", "personal care robot", "care and welfare robot"). As it is not a technical term and in some ways open to interpretation the author determined the following characteristics of an assistant robot as basis for this report.

[2]See the definition of SMEs by the European Commission:
http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition/index_en.htm

1. A human assistant robot is a service robot.
    - A service robot "*performs useful tasks for humans or equipment excluding industrial automation applications*" [1].

2. A human assistant robot is used for welfare purposes and livelihood support, excluding medical applications.

3. A human assistant robot provides physical and/ or mental support (social interaction, communication and monitoring).

4. A human assistant robot typically supports care patients (including those with physical and mental impairments, such as walking impediment and dementia), the elderly and caregivers (formal and informal)

5. Typical types of human assistant robots include:
    - mobile servant robots ("*travelling to perform serving tasks in interaction with humans*"[1])
    - physical assistant robots ("*physically assisting a user (patient or caregiver) to perform required tasks by providing supplementation or augmentation of personal capabilities*", including wearable suits or non-medical exoskeletons for physical assistance[1])
    - person carrier robots ("*transporting humans to an intended destination*"[1])
    - monitoring robots (monitoring patients and/ or the elderly, supply of care at home utilising tele-care)
    - companion robots (stimulating patients with cognitive disorders, encouraging social behaviour and eliciting emotional responses)
    - care facility logistics robots (improving the working environment, optimising the work flow, being highly collaborative with staff)

This report's scope of observation explicitly excludes medical service robots, such as robotic surgical systems, because they are considered medical devices and would therefore require a separate market analysis. Also excluded are service robots for general use, such as social robots that communicate and interact with humans for entertainment or information purposes and robots assisting in human chores (floor cleaning, mowing, pool maintenance etc.).

3 Overview -The Market for Human Assistant Robotics

> *"Historic market growth patterns in other areas of robotics manufacturing suggest that, when fully commercialized, the personal assistive […] robotics industry will be a source of strong future industrial economic development."* [2a]

3.1 General global development

According to the World Robotics Report 2015 by the International Federation of Robotics (IFR) the number of sold service robot units went up by 11.5% from 2013 to 2014 producing an increased sales value of USD 3.77 billion(JPY 422.1 billion or EUR 3.42 billion[3]) [3].

Within this sector impairment assistance robots have taken off as anticipated showing a sales increase of 542%. Robots for personal transportation are also predicted to gain more importance in the future. From 2014 to 2017 the sales of robots for elderly and handicap assistance are predicted to reach about 12.400 units with the further expectation that this market will increase substantially within the next 20 years. According to two different market studies the robotic exoskeleton sector might significantly contribute to that. With an annual growth rate of 72.51% over the period 2014-2019, as well as an annual growth rate of 39.6% over the period 2014-2025 the sector is predicted to reach USD 1.8billion (JPY 201.52 billion or EUR 1.63 billion) in 2025, up from USD 68 million (JPY 7.61 billion or EUR 61.68 million) in 2014 [4], [5]. Currently

[3]Used exchange rate of US dollar to Japanese yen/ US dollar to euro: February 24th, 2016

leading this sector are lower body exoskeletons, for example those that enable quality of life. However, the stronger potential for future growth is expected of commercial systems like low power restraint-type physical assistant robots, which amplify or augment the capabilities of users, such as caregivers [6].

3.2 The Japanese market

When it comes to the Japanese market in particular both the New Energy and Industrial Technology Development Organisation (NEDO) and the Ministry of Economy, Trade and Industry (METI) draw a similarly positive picture. Besides the fact that the current Japanese robotics industry mainly focuses on the production of industrial robots, there still is the forecast of rapid future growth in the area of nursing care and welfare.

The market for nursing care robotics (with JPY 16.7 billion accounting for about 4.5% of the service robotics sector in 2015) will approximately increase by more than 3 times to JPY 54.3 billion in 2020 and even up to JPY 404,3 billion in 2035 (see Figure 1, Figure 2 and Table 1). Japan's government has set its own sales target of JPY 50 billion to be reached in 2020 [7].

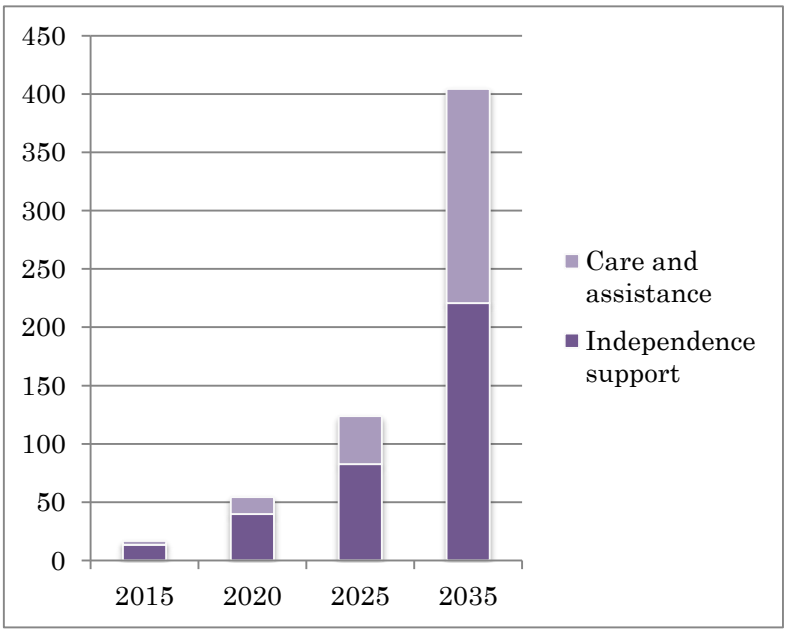

Figure 1 - Market growth of nursing care robots 2015 to 2035 in JPY billion (Source: METI/ NEDO (April 2010): "Forecast of the Future of the Robot Industry Market ")

Nursing care robot for	2015	2020	2025	2035
Independence support	JPY 13.4 bn	JPY 39.7 bn	JPY 82.5 bn	JPY 220.6 bn
Care and assistance	JPY 3.3 bn	JPY 14.6 bn	JPY 41.4 bn	JPY 183.7 bn
Service robots for				
Movement support (professional use)	JPY 5.0 bn	JPY 116.2 bn	JPY 619.0 bn	JPY 675.9 bn
Movement support (personal use)	JPY 2.1 bn	JPY 49.8 bn	JPY 265.3 bn	JPY 289.7 bn
Watching over, protection, communication	JPY 0.3 bn	JPY 1.1 bn	JPY 3.6 bn	JPY 34.1 bn

Table 1 - Sales value of service robots meant for nursing care and human assistance from 2015 to 2035 in JPY billion(Source: METI/ NEDO (April 2010): "Forecast of the Future of the Robot Industry Market“)

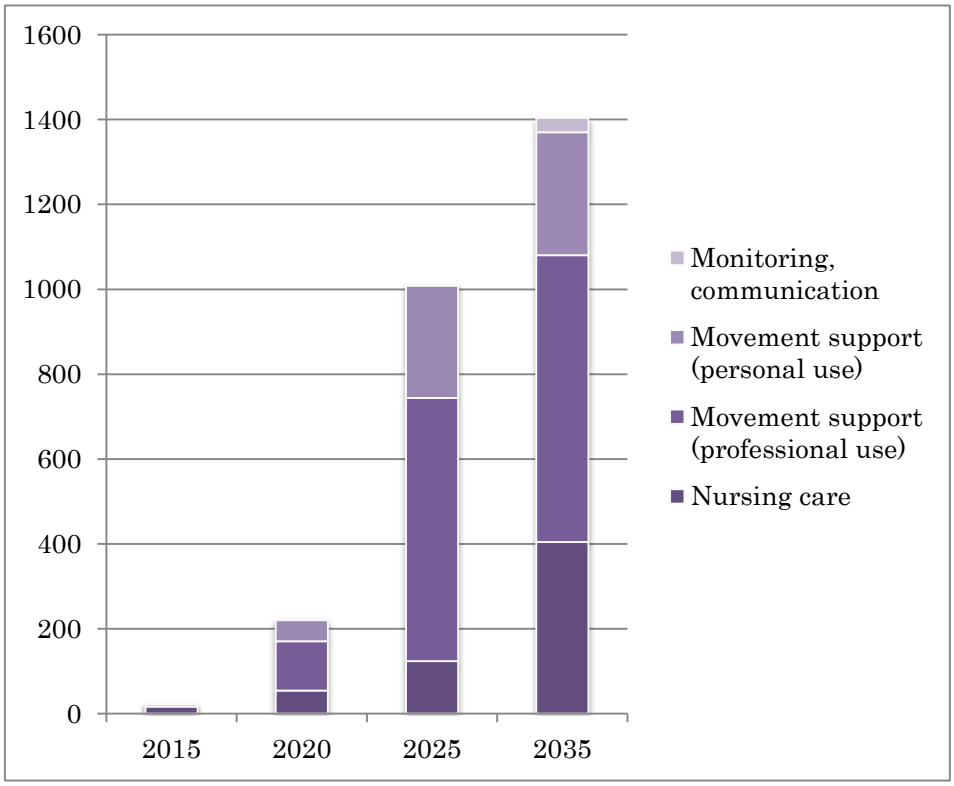

Figure 2 - Share of market growth of service robots meant for nursing care and human assistance from 2015 to 2035 in JPY billion (Source: METI/ NEDO (April 2010): "Forecast of the Future of the Robot Industry Market “)

3.3 RoboTech and nanotechnology

Contributing to the sector of human assistance robotics the "RoboTech" (robot technology) sub-sector that covers a wide range of components and parts[4] used to build and maintain robots is of further importance. Japan's component industry is said to be highly established [8], not only enjoying benefits in areas like weight decrease and production engineering, but having a 90% market share in key robotics elements [9]. With a market worth JPY 177 billion in 2015 it is expected to triple in size by 2020 to JPY 451.6 billion and again to grow by almost 3.5 times to JPY 1.56 trillion in 2035 [10].

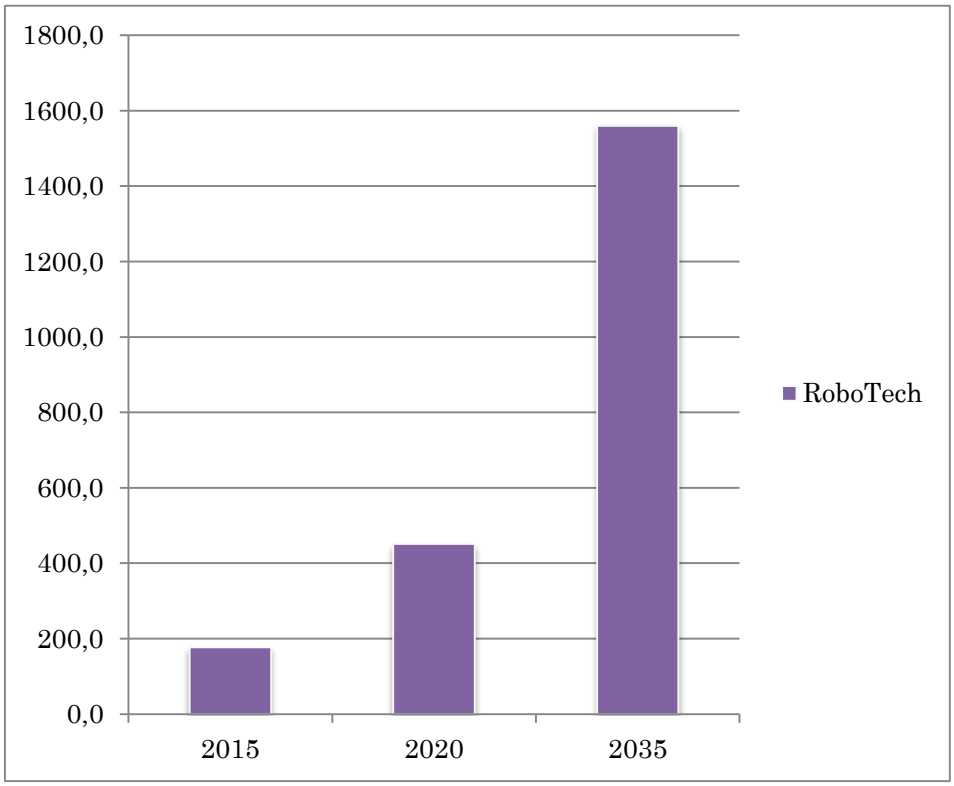

Figure 3 - Growth of the RoboTech market from 2015 to 2035 in JPY billion (Source: METI/ NEDO "Forecast of the Future of the Robot Industry Market (Issued in April 2010)"

[4] Sensors, servomotors, actuators, joints, manipulators, connectors, robotic cables etc.

The good prospects that are assumed for the RoboTech sector are expected to be supported by the shift towards nanotechnology. Its introduction not only allows for even smaller components, but thus for miniaturised robots that are suitable for the application in people's homes [10] which is highly desirable in case of human assistant robots.

A slightly detailed view on which components are of special interest to Japanese manufacturers was offered by this survey's results. The majority of the Japanese interviewees mentioned various kinds of sensors that are mainly needed to accomplish computer vision and recognition of speech and touch. Targeted applications therefore include communication and monitoring but also the proper transfer of humans, fetch and carry capabilities, as well as remote control, for example via mobile phones.

Survey box 1 - Japanese and European companies asked about essential RoboTech components in order to develop human assistant robots

Compared to hardware components, software is considered a market weakness. As Japan is a manufacturing nation and still leads in industrial robotics, the United States, for instance, has taken a lead in terms of software [11].A recent software contest for Japan's humanoid "Pepper"[5] seems to exemplify this problem, specifically for the nursing care sector. As the winning team (Fubright Communications) provided an app enabling Pepper to interact with dementia patients by simple conversations, scheduling medication intake and tele-medicine (reporting to a doctor via the Internet) the need for such software was demonstrated [12]. A similar contest took place in August/ September 2015 when, for the second time, the Toyota Motor Corporation held a "Hackathon" to jumpstart innovation in regard to its Human Support Robot (HSR). Teams from academia, research and corporate entities were competing to create the most

[5] Pepper is sold by SoftBank, a Japanese telecommunication and Internet corporation that acquired the humanoid's original French manufacturer Aldebaran Robotics in 2013 and made it its subsidiary.

innovative application for the robotics device. Also, Toyota planned to loan HSRs to Japanese partner organisations, mainly in academia and research, who would then share their software development [13].

3.4 Expected technologies to be developed

In addition to economic projections METI established an action plan to foster core technology development for next-generation robots (fiscal year 2015 to fiscal year 2019). Emphasis is primarily placed on core technologies, such as artificial intelligence (AI) and technology for automated behaviour based on human behaviour and the environment. Similarly, sensor and cognition systems, mechanisms, actuators and their control systems, as well as platform technologies are considered to have a significant impact on society when implemented [14].

4 Demographic Challenges and Resulting Trends

According to a recent official census, Japan's population decreased by 947,345 people between 2010 and 2015 representing the first decline since the beginning of official census recordings in 1920 [15]. As a result of the baby boom generation reaching the age of 65 years at around the same time (2012 to 2014) the ratio of elderly as a share of the total population will continue its fast-paced increase. It is predicted to rise to 30% in 2025 and to 40% in 2060[16].In 2010 the MHLW additionally stated that Japan needed an estimated two million nursing care workers based on the number of care recipients. However, even then the actual number of nursing staff only amounted to 1.33 million but the number of caregivers needed was predicted to further rise to 4 million by 2025[17].

The needs arising from those demographic challenges represent a major driving factor. Since alternative approaches, such as the review of Japan's immigration policy to counteract the declining workforce[6], are not seriously taken into

[6] Japan issues far less work visas a year as necessary. It's only a fraction of the number of immigrants needed annually to prevent its population from shrinking.

consideration the utilisation of robots is seen as the solution. Therefore nursing care (and medical) robotics is expected to grow the fastest within the sector of service robotics [10].

4.1 Scopes of application based on societal trends and characteristics

When asked for short- and long-term trends Japanese representatives of industry and research did respond quite cautiously. To begin with, none of the questioned parties directly addressed a nationwide implementation of assistant robotics in the Japanese society in the near future. They rather referred to a generally rising interest in robotic technology accompanied by much extended research. More particular trends included the rising popularity of communication robots, as well as the more widespread use of robotics for elderly care support, rehabilitation and physical assistance. When it came to the long term the outlook did not significantly change.

Survey box 2 - Japanese companies and research facilities questioned about short- and long-term trends in human assistant robotics in Japan

4.1.1 Elderly single households

Elderly citizens living alone have become a common social issue in Japan that, among others, most often involves the nation's senior population over 65 years. Today, the elderly being cared for in three-generational households no longer represent one of Japan's social characteristics, but a rarity (they account for less than 20% of all Japanese households) [18]. According to the National Institute of Population and Social Security Research (IPSS) one-person households of elderly individuals will show a particularly sharp increase from 9.6% (4.98 million) of all Japanese households since 2010 to 15.4% (7.62 million) in 2035 [19].

<u>Possible robotics solution</u>

Since elderly people are now more likely to reside away from their families and

live alone due to the shortages within the nursing care system [20] this supports the argument that such a development will inevitably lead to robots in the role of companions that ease the feeling of loneliness [21].

Image 1 - Unazuki Kabochan (© PIP Co., Ltd.)

4.1.2 Care due to disease or disability

The probability of being in need of care is increasing with age but also depends on other influencing factors. Thus, the elderly are not the only age group that will benefit from support and assistance by robotic devices. Heart diseases, for

example, represented the second most common cause of death in Japan in 2013 [22] and can require care in the aftermath. Also chronic conditions such as high blood pressure and diabetes which are seen as some of the biggest risk factors for stroke in Japan, apart from age, increase the likelihood of need for care [23]. Since chronic diseases, as well as accidents can further lead to disabilities the risk of needing nursing care is even higher.

Possible robotics solution

Care following a severe illness or being related to chronic diseases most often requires long and frequent visits to the doctor, in some cases even input from multiple specialists who are not necessarily located in the same area. Robotic solutions, such as tele-care robots, may address the need for a less time-consuming treatment by providing remotely located physicians with a means of medical supervision. Assistant robotic platforms like that can be used both in healthcare facilities with the patient being hospitalised or at the patient's home allowing them and their family to keep in touch with doctors and nurses [24].

Image 2 - VGo (© VGo Communications, Inc.)

In case of physical disabilities, affecting around 3.94 million Japanese in 2014 (one out of 32 people in Japan) [25], there are different needs that can be positively impacted by the use of assistant robots. Patients with impairments or disabilities of the lower limb, for example, benefit particularly from therapy with walking assistant robots, walking frames or exoskeletons, which has already proven effective in Japan and in European countries[7]. Such walking assist robot, for instance, can make patients feel much more comfortable and in control. Instead of being supported and led by several caregivers they can engage more actively in the process of recovery, which not only means more independence but also less stress both for patients and caregivers.

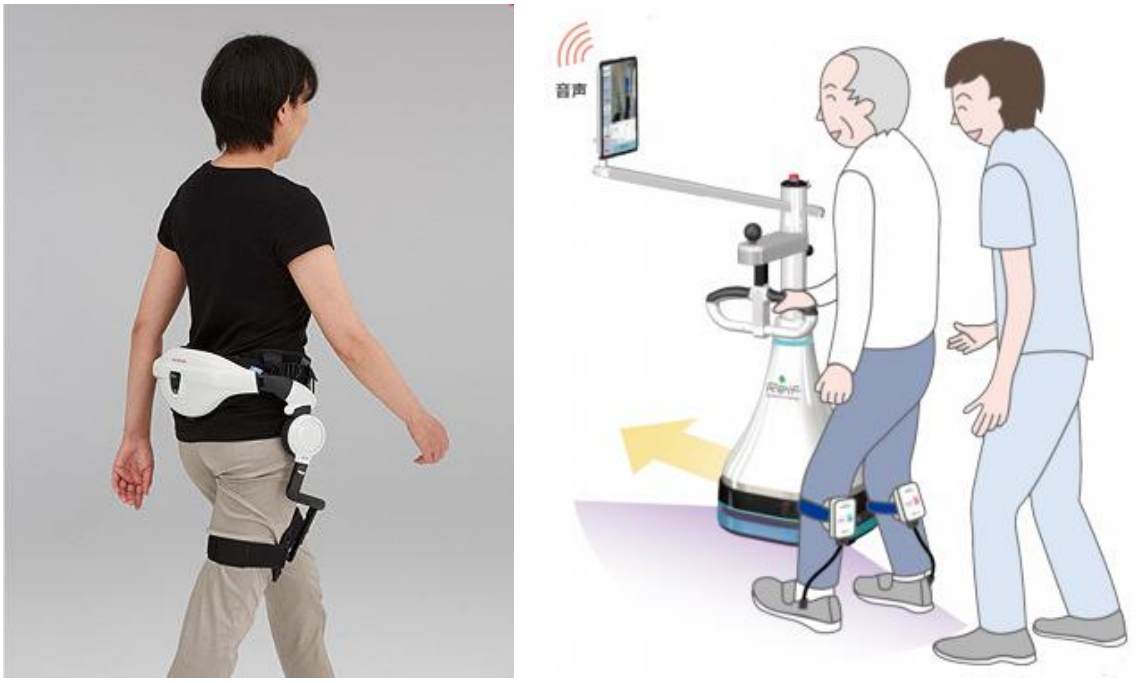

Image 3 - Honda Walking Assist (© Honda; left image) and Soutenir (© REIF Co., Ltd.; right image)

4.1.3 Long-term care

2.7% of the Japanese population (ca. 3.4 million people) received long-term care in 2013, mostly consisting of elderly aged 80 years and above followed by people aged between 65 and 79 years [26]. According to the MHLW, 6.3% of 70- to

[7] Information gathered from interviews and presentations.

74-year-olds, 26.9% of 80- to 84-year-olds and nearly 70% of people over 90 years are generally in need of nursing care [27]. Three of the four main reasons of long-term care in Japan are cerebrovascular disease, dementia and age-related weakness [28]. While instances of cerebrovascular disease are projected to decrease by 50% in 2050 [29], the number of elderly having dementia, being physically weak or bed-ridden will rise from about 9 million people in 2010 to roughly 12 million in 2025.

Possible robotics solution

Despite physical support for weak elderly that can be achieved by robotic lifting aids and assistant robots designed for personal care (bathing, toilet use, eating etc.), dementia patients require different and more specific attention. The care for a senile person is problematic, because it can be a severe emotional burden[8]. Assistant robots will not be a complete solution to this problem but to a certain extent they can provide relief.

In cases of dementia and forgetfulness, robots designed for communication and monitoring are of help not only to the elderly but to their families. They combine several concepts that have proven to be effective (e.g. improving medication adherence by reminding) or valuable (e.g. a system to input and share information among family and professionals) and show the potential for improving elderly people's social participation, autonomy and independence. Having a cute or animal-like design can also encourage patient-robot interaction, which can positively affect the physical and mental condition of senile elderly [31]. For formal and informal caregivers the use of assistant robots primarily means less stress and therefore a lower risk of burning out or directing their anger at patients or relatives.

[8] There have been several cases in Japan where people with dementia were abused or even killed by family members or caretakers [30]

Image 4 - left: NAO and Pepper (© Aldebaran Robotics, SoftBank Group), top right: Palro (© Fujisoft), down right: PaPeRo petit and R500 (© NEC: "Courtesy of NEC Corporation. Unauthorized use not permitted.")

4.1.4 Types of long-term care

The elderly in Japan strongly prefer ageing in their own home as this not only allows them to choose independent living over nursing care environments but also for a life of dignity and under their own conditions. Numerous studies have shown that this way of ageing provides a better quality of life. As the Japanese government very much supports long-term care at home and has created an insurance system that does the same[9], Japan is one of the few countries where people are cared for professionally more at home than in a facility.

[9] The Long-Term Care Insurance Act covers both fees for renting nursing care devices and expenses for purchasing some devices. In support of people with disabilities the Supporting Independence for People with Disabilities Law, on the other hand, covers expenses for purchasing and repairing assistive devices [32].

Possible robotics solution

Assistant robots may be useful in order to support home nursing personnel more efficiently during its work or even partially replace it by enabling family members to care for their relatives.

4.1.5 Importance to caregivers

With regard to nursing care staff and informal caregivers, carrying and lifting patients, for example from a bed to a wheelchair, is the heaviest physical burden they have to bear. As a result 70% of caregivers complain about backaches [33]. In addition, more than 50% of Japan's caretakers are at least 60 years old [34].

Possible robotics solution

Robotic devices like lifting and mobility aids are not only considered to lessen the physical burden, prevent work-related injuries and enable nursing care staff to work longer hours. They might also have a significant influence on how long caretakers can continue working later in life.

Image 5 - Resyone Wheelchair-Bed (© Panasonic)

4.2 User characteristics and economic factors

Not only societal developments can lead to new scopes of application. Specific user characteristics are equally worth having a look at.

4.2.1 Acceptance of robotics

In the early stages of care robotics, even in Japan, its introduction took off slowly due to mistrust and doubt of technology. The first assistant robots such as Paro, an electronic harp seal that was developed to keep dementia patients occupied, initially did not engage nursing home patients to a large extent[10]. Other companies had to discard their robot projects, because of lacking interest. The problems seen ranged from rejecting robots in favour of a human touch to the elderly people's incapability of handling the technology [35].

Since elderly care research and development have grown they have not only led to assistant robots with greater functionality but also to their proliferation, and hence a broader consumer acceptance. Despite initial reservations, Japanese elderly nowadays seem to quickly warm to this kind of technologies. A recent nationwide survey implemented by the ORIX Living Corporation, an operator of elderly homes, even showed that about 80% of the participants were positive to the introduction of robots mostly because they feel less hesitation towards them [33].

In general, the acceptance of robotics in healthcare is based on at least three basic requirements:

1. Motivation for the use of a robot
2. Its ease of use
3. Being physically and emotionally comfortable with it

Assistant robots that fulfil those conditions are very likely to be accepted by the

[10] Despite the difficult start, Paro has been successfully in use in Japan and throughout Europe since its introduction in 2003.

elderly, patients and caregivers. However, underlining the relevance of minimal technology requirements, it is argued that assistant robots meant for human assistive care will "*have to meet certain thresholds of manoeuvrability, dexterity and abstract reasoning*" [2b] in order to be acceptable to patients and the elderly.

When asked about user acceptance the answers of the Japanese interviewees ranged from "completely comfortable" and "indifferent" to "completely uncomfortable". This seems to underline the weak relationship between developers/ manufacturers and users, as there is no clear trend.

European surveyees, on the other hand, more often referred to their users as being "completely comfortable" or "indifferent". Since especially Western European countries (e.g. Denmark and Sweden) are known for user-driven technology development and the respective test environment, the better acceptance of robots for human assistance might be explainable by a greater user involvement.

Survey box 3 - Japanese and European interviewees questioned about the level of user acceptance of human assistant robots

4.2.2 Age and gender of users

Since 1985 (except for 2011) Japanese women have had the longest average life expectancy at birth worldwide. In 2014, they peaked at 86.83 years while Japanese men ranked third at 80.50 years. Among the elderly women generally represent the majority and continue to make up a large proportion with advancing age. In Japan due to living longer than men and particular patterns in partnership[11] women are more likely to live alone at an older age. With loneliness being a major prediction, women might have great needs for human assistant robotics as they grow old, mostly in terms of social connectivity [36].

[11] Divorces among elderly couples are not uncommon in Japan. One of the leading causes is the "Retired Husband Syndrome", that is physical symptoms of stress due to being forced to deal with the recently retired husband and his demands.

Additionally, as reported by the MHLW 85% of caregivers in Japan are women[34], which means an increased need, as they might not only use robotic devices for personal purposes but also to support others.

4.2.3 Economic factors

The impact of Japan's ageing population and shortage of professional caretakers is also reflected in the economic pressure on its healthcare system. In 2014 the old-age-dependency ratio[12] amounted to 42%, that is, one elderly citizen depending on 2.3 Japanese at working-age [37], which is predicted to rise to more than 70% by 2050. Thus, a decreasing number of people are paying into the system while demand for expensive long-term care increases. For instance from 2005 to 2013 the annual growth rate in public expenditure on long-term healthcare for at-home care was 8.7% and 2.2% for institutional care which totals 2.1% of Japan's Gross Domestic Product (GDP) in 2013[26].

The use of human assistant robotics is expected to directly reduce the expenses of healthcare for the elderly. Studies already show the immense potential of robotic assistant devices to deliver economic savings in hospitals and nursing facilities [2]. Since human help is costly robots that can be rented would be a bargain compared to costs for care personnel. In the same way successful therapy approaches involving assistant robotics can result in lower social costs after the patient has finished the treatment.

Furthermore and according to the OECD, the use of robotic assisted technology could not only save money during elderly care but also prior to it by delaying elderly people's entrance into nursing homes or hospitals in the first place. Elderly who have access to assistant robots that provide them with interaction of any kind (e.g. communication with family members, doctors, the robot itself etc.) are more likely to choose this option over being hospitalised or relocated to a nursing facility [2].

[12] People aged 65 years and older to the working-age population aged between 15 and 64 years

Another economic factor is care by family members. The argument goes that intensive care is associated with a reduction in labour force attachment because people who wish to care for relatives need to withdraw from working life to a certain extent. In such cases the costs of nursing not only mean companies' losses of employees and therefore possible economic damage. They most of all include a higher rate of poverty among informal caregivers of working age, which might be partially compensated by the use of assistant robotics depending on how severe the patient's illness is [26].

4.3 Limitations

Given the present state of technology a significant influence of assistant robotics on the imbalance between caregivers and patients might still be out of reach. Hypotheses about robots endowed with sufficient technical abilities that supplant caregivers at home are based on the assumption of major improvements in AI, mobility and sensor systems. Rather than a replacement for human caregivers assistant robots are more likely to be a complement to them [38]. As for today, their assistance might be limited to the improvement of efficiency and productivity, as well as to helping caregivers deal with physical burdens and the ever-increasing workload.

In terms of market strengths and opportunities, the Japanese parties surveyed seem to generally share the view in regard to the arguments mentioned above. While putting strong emphasis on the Japanese people's positive perception of and empathy for robots, the nation's rapidly ageing is both accepted as challenge and taken as opportunity. The growing number of elderly and people with dementia needing care is expected to have positive effects on the market's growth. The shortage of caregivers serves as similar argument. In this context it is assumed that not only the need for robotics in healthcare is rising but also its acceptance.

Survey box 4 - Japanese companies questioned about strengths and opportunities in regard to the Japanese market for human assistant robotics

5 Market Environment

5.1 Key Players and companies supported by the Japanese government

Currently, there seems to be a manageable number of Japanese companies operating in the field of human assistant robotics. However, it needs to be noted that several of the companies listed below have not yet entered the market in terms of commercialising their assistant robotics products. Especially among those being supported by METI and NEDO several firms are still in the process of development with their expected sales dates ranging from 2016 to "not yet decided".

Transfer aids(supported by METI/ NEDO)	
Cyberdyne Inc.	http://www.cyberdyne.jp/
Kikuchi Seisakusho Co., Ltd.	http://www.kikuchiseisakusho.co.jp/en/
Fuji Machine Mfg. Co., Ltd.	http://www.fuji.co.jp/e/
Muscle Corporation	http://musclecorp.com/english/index.php
Panasonic Corporation	http://panasonic.jp/
YASKAWA Electric Corporation	http://www.yaskawa.co.jp/en/

Table 2 - Japanese companies developing transfer aids (Source: http://robotcare.jp/?lang=en)

Mobility aids (supported by METI/ NEDO)	
Kawamura Cycle Co., Ltd.	http://www.kawamura-cycle.co.jp/
RT.WORKS Co., Ltd.	http://www.rtworks.co.jp/
Azbil Corporation	http://www.azbil.com/index.html
Imasen Engineering Corporation	http://www.imasengiken.co.jp/
NSK Ltd.	http://www.jp.nsk.com/
Shintec Hozumi Co. Ltd.	http://sales.shcl.co.jp/
YMP-Mundus Corporation	http://www.mundus.co.jp/
Mitsuba Corporation	http://www.mitsuba.co.jp/english/

Table 3 - Japanese companies developing mobility aids (Source: http://robotcare.jp/?lang=en)

Toileting aids(supported by METI/ NEDO)	
TOTO Ltd.	http://www.toto.co.jp/
Aronkasei Co.,Ltd.	http://www.aronkasei.co.jp/
Nihon Safety Co., Ltd.	http://www.nihonsafety.com/english/index.html

Table 4 - Japanese companies developing toileting aids (Source: http://robotcare.jp/?lang=en)

Monitoring systems (supported by METI/ NEDO)	
Pip Co., Ltd.	http://www.pipjapan.co.jp/english/index.html
IDEAQUEST Co., Ltd.	http://www.ideaquest4u.com/english/
King Tsushin Kogyo Co., Ltd.	https://www.king-tsushin.co.jp/
NK Works Co.,Ltd.	http://www.nk-works.co.jp/english/
Clarion Co., Ltd.	http://www.clarion.com/jp/ja/top.html
Super Regional,Inc.	http://www.super-r.net/

Table 5 - Japanese companies developing monitoring systems (Source: http://robotcare.jp/?lang=en)

Communication:	
tmsuk Co., Ltd.	http://www.tmsuk.co.jp/english/robots.html
NEC Corporation	http://www.nec.com/
Vstone Co., Ltd.	http://www.vstone.co.jp/english/
Okamura Corporation	http://www.okamura.jp/
Ory Laboratory	http://orylab.com/
Intelligent System Co., Ltd.	http://intelligent-system.jp/
Pip Co., Ltd.	http://www.pip-club.com/english/
Fuji Soft Incorporated	http://www.fsi.co.jp/e/

Table 6 - Japanese companies developing robotic communication devices (Source: EU-Japan Centre for Industrial Cooperation 2015: "Robotics in Japan")

RoboTech: Servo motors	
Omron Corporation	http://www.omron.com/
Panasonic Corporation	http://panasonic.net/
Hitachi Industrial Equipment Systems Co., Ltd.	http://www.hitachi-ies.co.jp/english/
Fanuc Corporation	http://www.fanuc.co.jp/eindex.htm
Fuji Electric Co., Ltd.	http://www.fujielectric.com/

Mitsubishi Electric Corporation	http://www.mitsubishielectric.com/worldwide/
Yaskawa Electric Corporation	http://www.yaskawa.co.jp/en/

Table 7 - Japanese companies developing servo motors (Source: EU-Japan Centre for Industrial Cooperation 2015: "Robotics in Japan")

RoboTech: Sensors	
Murata Manufacturing Co., Ltd.	http://www.murata.com/
Kyowa Electric Instruments Co., Ltd.	http://www.kyowa-ei.com/eng/
Showa Measuring Instruments Co., Ltd.	http://www.showa-sokki.co.jp/English/index_e.html

Table 8 - Japanese companies developing sensors (Source: EU-Japan Centre for Industrial Cooperation 2015: "Robotics in Japan")

RoboTech: Robot vision	
Canon IT Solutions Inc.	http://www.canon-its.co.jp/
Sharp Manufacturing Systems Corporation	http://sharp-world.com/sms/en/
Seiko Epson Corp.	http://global.epson.com/
Panasonic Industrial Devices SUNX Co., Ltd.	http://www2.panasonic.co.jp/id/pids

Table 9 - Japanese companies developing RoboTech for robot vision (Source: EU-Japan Centre for Industrial Cooperation 2015: "Robotics in Japan")

5.2 Import and Export

The value of imports of human assistance robotics in general cannot be accurately determined, because of its diversity. Although, there is a specific categorisation for industrial robots under the "Harmonised System" (HS)[13], there is no such classification for human assistant robots. Determining the respective HS code may be decided from case to case. This way a person carrier robot may be categorised as "lifting machinery", whereas a companion robot may fall under the code for "sound apparatus"[14]. Further problems might arise due to the immaturity of the market.

[13] Developed by the World Customs Organization (WCO) and used by countries/ economies as a basis for Customs tariffs and for the collection of international trade statistics.

[14] Information gathered from correspondence with the Japanese Customs

5.2.1 Too early for assessment

The industry is considered to be still in its infancy. Market growth at a significant pace and therefore an opening up of the export market was expected to start as of 2015 after the establishment of the first international safety standard for personal care robots (ISO 13482, established in 2014) [39].

5.2.2 Lacking interest in commercialisation

As early as 2006 the Japan External Trade Organisation (JETRO) found that Japanese companies are putting more effort into technological development than market deployment, which is still subject to criticism. Due to the market being not yet mature enough, manufacturers might be unable to get a good read on their assistant robots' market potential dampening their interest in pursuing commercialisation. Additionally, there are companies actively developing advanced robotics technologies that are not meant for a particular purpose other than to represent technological prowess [40].

5.2.3 Slow move towards exporting

If product development is proceeding slowly no manufacturer will move aggressively towards exporting. They would rather concentrate on establishing their position in the domestic market first, which makes sense in regard to servicing human assistant robots. A further influencing factor might be the acceptance of utilising robots for human care, which is said to be higher in Japan than in certain markets overseas [40].

This report's research showed that at least four of the determined and contacted 49 European companies have partnered up with Japanese agents to distribute their assistant robotic products (hardware and software) in Japan. The questionnaire additionally revealed that among the Japanese interviewees only one imports specific components from Europe, such as servomotors. Among the European companies one imports Japanese robotic cables and connectors, but none of them exports components and/ or technologies. Only one European company exports its final product to Japan.

Survey box 5 - Japanese and European companies asked about importing and/ or exporting their products, technologies and/ or components

5.3 Distribution

The channel of distributing human assistant robots in Japan can depend on the target customer group as well as on the type of assistant robotic devices. In general it has to be noted that distribution through multiple intermediaries is one of Japan's distinctive characteristics [41].

5.3.1 Selling (or renting) to hospitals

Hospitals are primarily in need of assistant robots that lessen physical or mental burdens for the nursing staff or at least contribute to an efficient time management. Although such devices are considered non-medical equipment the same distribution channels as used for medical equipment might apply.

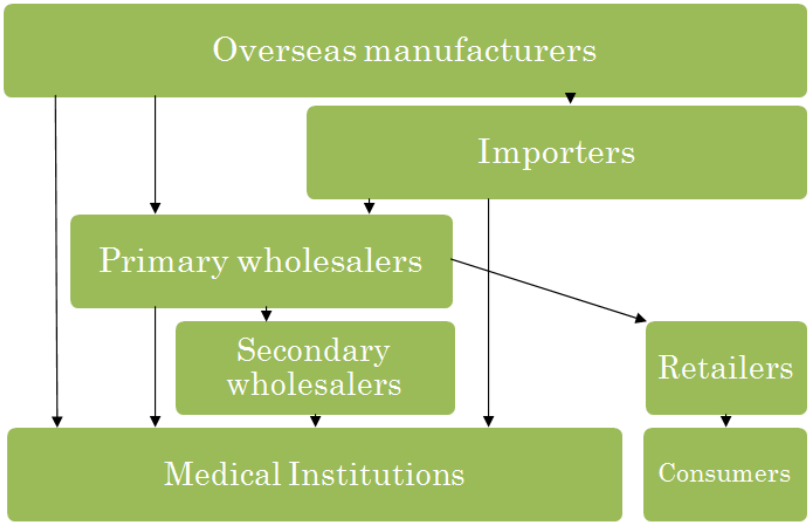

Figure 4 - Distribution channel for selling medical equipment to hospitals

It is common for manufacturers to sell through first-tier, second-tier and other intermediary wholesalers to medical institutions (direct transactions are less prevalent in Japan than in Western countries). However in the case of high-priced medical equipment, such as MRI's, direct transactions are generally the distribution channel between the hospital and manufacturer. Since human assistant robots themselves still represent a highly priced segment, the latter might prevail [42].

5.3.2 Selling (or renting) to nursing care facilities[15]

In contrast to hospitals, nursing homes not only need human assistant robots for relieving caregivers but for keeping patients and the elderly occupied. In most cases, welfare device companies are the usual distribution channel for nursing homes. If a manufacturer of assistant robotics has no history of selling to nursing care facilities they can try to sell their product directly or involve a rental or leasing company if requested by the facility. One of the most known distributors of nursing care robots is Daiwa House, a construction company that recently entered the business of distributing care robots.

[15] Information gathered from interviews.

5.3.3 Selling (or renting) to individuals

If care is provided at home devices that can be easily used by the elderly and their family members are of need. In this case direct distribution from manufacturers to stores or the consumer through mail order services may become an important and growing channel.

In all cases, establishing trust through product quality and certification of safety will be essential to open up business, as the utilisation of human assistant robotics involves a close proximity to humans. For the same reason after-sale services might be equally important [42].

5.4 Market difficulties

Although Japan is the leading contributor to the development of human assistant robotics, the nation's manufacturers have not gained an empirically measurable market lead over those in the European Union (or the United States) yet:

> *"While Japanese manufacturers of assistive robotics have demonstrated an advanced level of technological sophistication, they are still restricted by the same combination of high prices, limited demand and lack of market standardisation that hinders market growth in the other regions of the world."* [2c]

5.5 Costs

Among others, high costs have led to Japanese companies re-directing their strategies in favour of less costly specific use devices instead of developing robots providing a wide range of domestic services. Such technology was said to be still at an early stage with little market penetration and very high introduction costs [43]. Additionally and due to the market's immaturity, the knowledge about how much is cheap or expensive in terms of pricing seems to be problematic. The price difference between a robot's prototype and its marketed version, for instance, can often only be guessed. As for complaints of health care professionals, robotic companies also seem to fail to adequately

evaluate their devices' costs during the R&D process [2].

A related problem arises from overly ambitious goals during the development process of human assistant robotics. Over-engineering - the gap between what engineers want to develop and what is actually needed - is a well-known risk. It is caused by perfectionism and addition of functions leading to more expensive and less reliable products. The Japanese government shares the view that the current development of care robots often results in devices that are too large and too costly to be actually considered for nursing care [44]. The 2015 report "Potential of Robotics for Ambient Assisted Living" [45] therefore stresses that the elimination of over-engineering can significantly contribute to cost reduction.

5.6 Demand limited by development

Reportedly, developers and manufacturers are considered to be partially responsible for the weak state of the market demand [2]. Interviews revealed that Japanese companies tend to develop assistant robots independently of existing needs. Instead of developing a technological solution to a specific problem the scope of application is of secondary interest. More detailed information could be gathered from a consultancy that specialises in technology transfer between Europe and Japan among others. The company highlighted the lack of user involvement in Japan, which supposedly results in the above-mentioned development strategy.

It is one of Japan's bigger problems to anticipate situations in which their robotic solutions could actually play a role [46]. To counteract the current tendencies the MHLW plans on establishing about ten centres throughout Japan by fiscal year 2016 where both the elderly and care professionals will come together for sharing their thoughts on care robotic technologies [44].

The fact that all Japanese survey participants, who answered the question related to user involvement, checked the box stating "No development without potential user involvement" might imply a very different perspective on when user involvement is most effective. It turned out that Japanese companies seem to involve users only after the initial development to conclude which improvements could be made during the further process. This not only extends the period up to commercialisation but also makes it very difficult to address current needs. Only one company seems to base its development on the needs of the targeted user group right from the beginning.

Survey box 6 - Japanese companies questioned about the importance of user involvement during the development process of human assistant robots

5.7 Demand limited by insurance spending

Reimbursement of expenses related to human assistant robotics in nursing care is considered necessary in order to encourage demand and therefore its wider use. According to the OECD, "*the market failure of at least one assistive robotic device [...] was caused by overly restricted reimbursement guidelines [...]*" [2d]. It is for this reason that Japan's government plans to review current nursing care insurance coverage to include these robots. Revisions supposedly have started to take place since fiscal year 2015 and will go on until fiscal year 2020 focusing on a more flexible reception and inspection of nursing care equipment.

A broader insurance coverage is not only needed to encourage users but manufacturers. As long as the nursing care insurance provides enough reimbursement (and users are willing to pay for the assistant robot) they can set a price that is high enough to cover their costs and generate profits. Due to an incentive like that more companies may gain access to the market even though it is not fully grown; for example those that are not eligible for public funding, as the Japanese government provides it for selected companies [47].

5.8 Standardisation

At first glance, standardisation did not seem to concern the Japanese respondents of the survey, as most of them answered "no" when asked for its necessity. On the other hand, while it is not considered to be an urgent issue for the moment, establishing standards seems to be important in the future. The reasons are simple: Due to the market's current state, the still small number of robots and the lack of clarity what robots should be able to do, it is too early for standardisation. Only one respondent answered "yes" relating to the importance of standards for increasing user confidence.

The complete opposite was demonstrated by the answers of the European respondents. Only one pronounced against standardisation whereas the rest underlined its necessity in terms of compatibility, safety and alleviation of the bureaucratic burden. Those different views might reflect the different focuses of both parties, with Japanese companies concentrating on technology development and European companies aiming at its market deployment.

Survey box 7 - Japanese and European companies asked about the importance of standardisation in regard to human assistant robotics

Since it is expensive to manufacture robots that can carry out precise tasks or have conversations, most assistant robotic devices are built in small quantities and the barriers to standardisation are high. Thus, an increase in demand and commercial exploitation is necessary to allow for mass production and standardisation. The absence of standards, however, prevents the commercial market from reaching an effective size and reducing costs.

An assumption made by the OECD is that "*it is likely that market-wide assistive robotics manufacturing standardisation will require the momentum of private corporations seeking commercial benefit [...]*" [2e] as it has happened

before in early personal computer industry[16]. To support company-driven standardisation the Japanese government established the "New Market Establishment Standardisation System" in July 2014 that allows for an accelerated development of national industrial standards. In contrast to the conventional process there is no need for industry consensus in case "*a single company that has strikingly advanced technology has difficulty making adjustments within the industry, (in case) drafting by small or medium companies is difficult, or (in case) the technology spans several industries*" [48].

However Japanese businesses typically face a convoluted bureaucracy when it comes to innovative approaches or new technologies. As for robotics, regulatory barriers outside of manufacturing are still high since robotic devices have always been required to comply with high safety regulations similar to those of the medical industry [9].

5.9 Ethical problems

In the same way as standardisation a more common concept of ethics may support the proliferation of robots. It is believed that robotics projects that do not consider ethics are more likely to face problems in regard to market entry [49], [50].

6 Strategic Policy Programmes

6.1 Funding schemes

With increasing national and international attention on Japan's service robotics in 2005, it became the government's objective to support R&D in this field, to create a new industry and to realise economic growth. Several projects and initiatives were launched to foster the introduction of human assistant robots into Japanese society [51], [52]:

[16] Industry standardisation began under the influence of computer manufacturers such as IBM and Apple that pushed for market shares in the early 1990's.

- Project for the Implementation of Livelihood Support Robots
  - Project period: fiscal year 2009 to fiscal year 2013 (five-year plan)
  - Competent body: METI, NEDO
  - Budget: JPY 6 billion (EUR 44 million) in total
  - Objectives: R&D for methods of safety verification; development of robots for livelihood support with integrated safety technology

- Project for Helping Putting Welfare Equipment and Nursing Robots into Practice
  - Project period: start in fiscal year 2011
  - Competent body: MHLW, The Association for Technical Aids (ATA)
  - Budget: JPY 83 million (EUR 615,000) per year
  - Objectives: Connecting places of development and care (advices by experts, delivering funding for monitoring surveys in care facilities) in order to create an environment that prompts practical use of robots; enforcement of test runs; as of fiscal year 2013, supporting the implementation of recommendations by experts

In 2012 and 2014 METI and the MHLW put particular emphasis on the need for human assistant robotics by officially determining five priority areas[17] for governmental support:

1. Transfer aids (wearable and non-wearable): Assistance in lifting and moving the elderly or otherwise impaired people to relieve caregivers of the physical burden
2. Mobility aids (for indoor and outdoor purposes): Walking support to help the elderly walk independently by themselves
3. Toileting aids: Can be placed outside the bathroom to ease the use for elderly persons or others

[17] In 2012 only four priority areas were formulated. As a result of a survey conducted in 2014 the fifth priority area was added.

4. Monitoring systems (for nursing care facilities and private homes): Tracking movements and whereabouts of senile and dementia patients
5. Bathing aids: Autonomously performing bed baths to keep bedridden patients clean

To promote the development and commercialisation of robotic devices in those areas METI and NEDO launched a Public Private Partnership (PPP) that put forth the "Project to Promote the Development and Introduction of Robotic Devices for Nursing Care" in 2013[18]. This programme's objectives included:

1. Human assistant robots that can be manufactured within three to five years to be sold as of fiscal year 2016
2. Human assistant robots that cost JPY 100,000 at most or 10% of their selling price when being rented by companies
3. The formulation and evaluation of standards for safety, performance and ethics

In fiscal year 2013 METI called for the first applicants to apply for subsidies of either two-thirds (SMEs) or 50% (large companies) of their total development costs. The draft budget for that year was set at JPY 2.39 billion. In May 2013 METI had selected 24 out of 46 applications following the first invitation to the project. Each of them was to receive a share of the total subsidy of JPY 800 million. Further invitations were scheduled following the first round of applications.

July 2013 (second invitation with focus on early adoption):

- 9 out of 16 applications were selected
- The total subsidy for those applicants was about JPY 380 million

[18] Project period: fiscal year 2013 to fiscal year 2017

August 2013 (second invitation with focus on regular adoption):

- 15 out of 26 applications were selected
- the total subsidy for those applicants was about JPY 430 million

May 2014:

- 51 entities (31 out of 47 applicants and 20 entities for projects continuing from fiscal year 2013) were selected
- The total subsidy for those entities was about JPY 1.82 billion

Further subsidies were announced by the call for applications for the "Project for Demonstrating the Introduction of Nursing Care Robots" starting in fiscal year 2015 that focuses on the support of actual demonstration trials in care facilities. The draft supplementary budget, JPY 2.05 billion in total, is meant for trials covering about 1,500 robots in 15 types of nursing homes [53].

6.2 New Industrial Revolution Driven by Robots ("Robot Revolution")

"*I plan to make robots a key pillar of our growth strategy.*"Prime Minister Shinzô Abe [54]

In late 2014 the Japanese government, under Prime Minister Shinzô Abe, proclaimed a "New Industrial Revolution Driven by Robots" or "Robot Revolution" as part of its revised "Japan Revitalisation Strategy". The newly established Robot Revolution Realisation Council[19], which brings together numerous experts, has held six meetings since then (status as of September 2014). Both its final report titled "Japan's Robot Strategy" as well as the later published "New Robot Strategy"[20] state a strategic action plan towards the realisation of the Robot Revolution for specific sectors suffering from severe labour shortage [53].

[19] Chair: Mr. Tamotsu Nomakuchi, advisor of Mitsubishi Electric Corporation

[20] Published on February 2nd, 2015 by the Headquarters for Japan's Economic Revitalization

As for the nursing care sector this five-year plan (2015 to 2020) primarily provides for a change in awareness of robotics as new caring methods. It is hoped that by using the newest robot technology both the ratio of caregivers and the ratio of care receivers who want to use robots or want them to be used will rise to 80% (currently 59.8% or 65.1%). Thus, not only development support but also encouraging users is considered to be essential [7],[14].

To achieve the strategy's particular objectives the Robot Revolution Initiative[21] was launched on May 15th, 2015 as an organisational platform. In fiscal year 2015, its first year of activities, the initiative has begun to establish several working groups (WG) of which the "Robot Utilisation Promotion Work Group" and the "Robot Innovation Work Group" are of most interest to the nursing care sector. Both WGs started working in September 2015 [55].

Robot Utilisation Promotion Work Group (58 members): With one goal being "*to set the stage for the introduction and proliferation of actual usable robots*" [56a] into the medical and care-giving sector, the Robot Utilisation Promotion Work Group has a direct influence. The WG's planned activities particularly focus on:

1. Identifying needs and prioritising them by feasibility,
2. Establishing collaborations on the prefectural level between technological experts (companies), prefectural technology centres, regional universities and prefectural government organisations,
3. Reusing donated robots and developing training programmes for technological education
4. Inter-sectorial exchange to establish societal barriers to the proliferation of robots, establish a common regulatory reform and address global machine and safety standards
5. Sharing information and experiences gained from successful robot

[21]The Initiative's members (300 as of August 2015) include representatives of relevant companies, business organizations, academia and research institutions working in conjunction with government agencies.

applications (including a nationwide data base for empirical knowledge).

Robot Innovation Work Group (80 members): The WG on Robot Innovation might affect the medical and care-giving sector in a more indirect manner by increasing interoperability and standardisation. Two of its three sub-working committees are responsible for:

1. Selecting a robotic platform that is applicable to each sector and each process, as well as promoting the development of modular hard- and software
2. Examining and proposing safety standards that will become internationalised [56]

6.3 Laws and regulation

6.3.1 International safety standards

Although robots have been widely used for years they also have been mainly restricted to the manufacturing sector with no or very little contact with people. As service robotics and human assistant robots have appeared on the scene a close proximity between humans and robots emerges. They already are capable of voice and gesture recognition as well as reacting to touch. Some robots can even connect to the human nervous systems by tapping into brain wave activity. The change in human-robot interaction requires a careful assessment of risks to ensure safety because assistant robots malfunctioning can result in serious or fatal accidents [57].

In the light of this development METI and NEDO started to collaborate on the "Project for Practical Application of Service Robots" as of fiscal year 2009. After having analysed data on robot safety, formulating safety standards and testing their verification a proposal was drafted and submitted to the International Organisation for Standardisation (ISO) [58].

ISO adopted Japan's proposal and issued ISO 13482 (Robots and robotic devices - Safety requirements for personal care robots[22]), the world's first safety standard for personal care robots. Published in early 2014 it was primarily meant to complement ISO 10218-1, a standard that covers safety requirements for industrial robots only.ISO 13482 "*specifies requirements and guidelines for the inherently safe design, protective measures, and information for use of personal care robots, in particular the following three types of personal care robots: mobile servant robot; physical assistant robot; person carrier robot.*" [1]

The Working Group (ISO/TC 299/WG 2[23]) that created ISO 13482 will update the standard as technology evolves. At the same time additional ISO guidance is being developed involving the foremost experts in this field [57]. In July 2014, the ISO 13482 safety standard was published in the Official Journal of the European Union after being harmonised with the European Machinery Directive [59].

In Japan ISO 13482 is expected to help manufacturers gain the trust of customers and to open up the market for new robots[60].Prior to the standard's publication, METI and the MHLW had already started to prepare safety guidelines for the selected priority areas. In 2013 METI chose the National Institute of Advanced Industrial Science and Technology (AIST) in order to carry out a project to formulate and evaluate standards for promoting standardisation [61].

6.3.2 Recent trends of safety approval for service robots

Japanese organisations currently involved with safety approval for service robots are the Japan Quality Assurance Organisation (JQA), AIST and the Japan Automobile Research Institute (JARI) among others. JQA established an approach to the safety certification of service robots which was based on the

[22] A personal care robot is defined as „service robot that performs actions contributing directly towards improvement in the quality of life of humans, excluding medical applications".
[23] Former ISO/TC 184/SC 2/WG 7

proposal submitted to ISO and its own previous efforts. AIST, JARI and other organisations have developed new testing methods at the Robot Safety Centre in Tsukuba (Ibaraki prefecture). In the future, private companies will be able to test their assistant robotic devices at the centre to verify if they comply with the ISO 13482 standard [58].

6.3.3 National standards and labelling

Compliance with national Japanese standards depends on assistant robots being medical or non-medical devices[24]. Since human assistant robots that are supported in accordance with the priority areas selected by METI are referred to as nursing equipment or robotic care equipment they are considered to be non-medical.

The Japan Industrial Standards (JIS), a non-mandatory voluntary standard can be taken into consideration to enhance sales potential and consumer trust and acceptance (all products are eligible for accreditation). Additionally, in case of government procurement, JIS marking can be an important determinant, since certified products will be treated with preference under Japan's Industrial Standardisation Law [62].

However published JIS standards referring to assistant robotics in any context so far only comprise JIS B 0187:2005, that is defining a vocabulary of main terms to be used concerning service robots. Standards listed as part of the Japan Industrial Standards Committee's (JISC) monthly plans for new JIS draft proposals are the following ones [63]:

- December 2013: "Robots and robotic devices - Safety requirements for personal care robots"
- April 2014: "Robots and robotic devices - Safety requirements for personal care robots - Static stable mobile servant robot with no

[24] See the World Health Organization's definition of „medical device": http://www.who.int/medical_devices/full_deffinition/en/

manipulator" (Part 1)

- April 2014: "Robots and robotic devices - Safety requirements for personal care robots - Low power restraint-type physical assistant robot" (Part 2)
- April 2014: "Robots and robotic devices - Safety requirements for personal care robots - Self-balancing person carrier robot" (Part 3)

The resulting draft of the "JIS B 8446" series of April 2014 (see above) was approved for enactment on December 10th, 2015 by the JISC's First Subcommittee.

To foreign factories the JIS marking system was open since the amendment of the Industrial Standardisation Law in 1980. According to this law "*[…] domestic or foreign manufactures (processors), importers, exporters or distributors voluntarily apply for certification on their products to the third party certification bodies […] that accredited by the competent minister, and they may affix a special mark (so-called JIS mark) on their products, that shows the products comply with the relevant JIS*" [64]. Both domestic and foreign factories are treated equally and can choose to be assessed either by a registered governmental or non-governmental certification body based in Japan or abroad [65]. Product certification bodies conduct a series of test to verify the products' compliance with JIS and audit the manufacturing facilities. If a factory successfully passes any product manufactured there will be authorised to affix the JIS mark [62].

6.3.4 Further regulatory discussions to be held in order to realise the Robot Revolution

For the purpose of enhancing utilisation of robots, further regulatory and structural reforms in terms of regulatory ease and rule setting are planned by the Japanese government. The following issues and underlying laws that are to be discussed might influence the regulation of human assistant robots [66]:

- Coverage under official nursing care insurance with respect to nursing care robots (Long-Term Care Insurance Act)
- A framework for consumer protection (Consumer Product Safety Act and Electrical Appliance and Material Safety Act)

Case 1: It is planned to make the system for accepting and reviewing requests for items falling under the nursing care insurance system more flexible (currently reviews are scheduled once every three years). For example, in order to quickly respond to technological innovation requests for insurance coverage by the item's developer shall be accepted as necessary. Requests concerning present items shall be quickly disseminated, while requests regarding the addition of new items shall be decided on by meetings of the competent committees[25] [7].

Case 2: If a human assistant robot would come under the Consumer Product Safety Act and/ or the Electrical Appliance and Material Safety Act, this robot would need to be certified in compliance with the mandatory Consumer Product Safety Mark PSC (Product Safety of Consumer Products Mark) and/ or the mandatory Product Safety Electrical Appliance & Materials Mark PSE.

According to JETRO "*the term 'consumer products' means any product to be supplied mainly for use by general consumers for their routine everyday activities (...). That is, all products supplied for use by general consumers and sold generally in the market (...)*" [67a]. Products excluded are specifically defined, whereas consumer products for themselves cannot be defined clearly due to their diversity and continuous technological innovation.

As for the Electrical Appliance and Material Safety Act total 116 items "*of electrical appliances and materials deemed likely to be dangerous or cause*

[25] The "nursing insurance welfare tool evaluation and review committee" and the "nursing care payment subcommittee of social security deliberation council".

trouble are defined as 'Specific electrical appliances', (...) [whereas 340] other items are defined as 'Electrical appliances other than Specific electrical appliances" [67b], [68], [69].

Also manufacturers of robots might be held liable under the Product Liability Act, since the law defines the term "product" as "*a moveable product which is manufactured or processed*" [70]. This law even applies to medical devices and pharmaceutical drugs.

Nevertheless, in Japan final regulations are still in progress. Although, there are efforts planned to simplify the regulatory framework for human assistant robots and new standards are actively developed it is not clear, yet, what Japanese laws are actually applicable. Correspondence with METI's Committee for Japanese Industrial Standards even implied that there might be no need at all to have assistance and nursing care robots certified in order to sell or rent them.

Japanese representatives questioned on the necessity of a regulatory framework did not demonstrate a common view. They answered either that it was too early for such regulations or that it was needed to formally establish the human assistant robotics industry. On the other hand, the majority of the European respondents pronounced in favour of established regulations but mostly without giving a specific reason. One of those surveyed argued that regulations would suggest a certain seriousness of the government to fund and implement human assistant robots. Others highlighted the importance of regulations to ensure minimal levels of user safety, as well as common and recognised references.

Survey box 8 - Japanese and European companies asked about the necessity of a regulatory framework for human assistant robotics

7 Technological Cooperation Potential

Research and development are a major focus of human assistant robotics in Japan. The following are some of the main institutions and organisations involved in research, development and fostering collaborations in that field.

7.1 Research Institutes and Centres

7.1.1 National Institute of Advanced Industrial Science and Technology (AIST)

AIST is one of Japan's largest public research organisations and focuses on the creation and realisation of technologies that are useful to the country's industry and society. Its Robot Innovation Research Centre examines particular target industries for improvement by the utilisation of robotics, develops protocols for safety evaluation of the applied robotic devices and analyses the results of the application. In particular it houses the "Project Unit of Robotic Devices for Nursing Care", a collaboration with teams of the Intelligent Systems Research Institute and the Human Informatics Research Institute. In regard to human assistant robots AIST is well known for developing the robot seal PARO [71].

7.1.2 RIKEN

As Japan's largest and most comprehensive research organisation for basic and applied science, RIKEN offers research in a diverse range of scientific disciplines including human assistant robotics. Its nursing care robots RIBA (2009), RIBA-II (2011) and ROBEAR (2015), which serve as mobility and lifting aids, have been developed in collaboration with Tokai Rubber Industries, Ltd. (RIBA and RIBA-II) and Sumitomo Riko Company, Ltd. (ROBEAR). Their predecessor, RI-MAN, was created by RIKEN's Bio-Mimetic Control Research Centre to help nurse the elderly [72], [73].

7.1.3 Japan Robot Association (JARA)

JARA aims to promote the robot manufacturing industry by encouraging research, robot development and the use of robot technology. The association strives to not only enhance the proliferation of advanced technology in the industry but to contribute to Japan's welfare, economic growth and living

standards. JARA's activities in regard to human assistant robots focus on its involvement in drafting standards, as well as the development of strategies and programmes for a greater use and studying ongoing trends [74].

7.1.4 Japan Automobile Research Institute (JARI)

JARI is an incorporated foundation that is dedicated to automotive testing and research including the safety of personal assistant robots. The institute is developing technologies for risk analysis and evaluation techniques for safety assessment. Since personal robots represent a new technology JARI utilises the technologies and information available from relevant industries such as the automotive and electric machinery industries [75].

7.1.5 Advanced Telecommunications Research Institute International (ATR)

ATR is a private company that promotes fundamental and innovative activities in research and development. In regard to R & D, ATR focuses on four areas one of them being "Life-supporting Robots". The associated "Intelligent Robotics and Communication Laboratories" aim at the advancement of core technologies for life care robotics in order to help the elderly, as well as physically challenged people. To achieve research outcomes ATR collaborates with various universities, research institutes and companies within and outside of Japan [76].

7.1.6 Robot Safety Centre

The Robot Safety Centre is a jointly established company by NEDO, AIST and JARI formed in 2010 in Tsukuba. Said to be the only facility of its kind worldwide it develops test methods for the safety verification of personal care and assistant robots. The Robot Safety Centre has four main test areas that allow for tests related to (1) driving (obstacle detection), (2) personal safety, (3) durability and (4) electromagnetic compatibility. In the future it is expected to provide certification services with the collaboration of the Japan Quality Assurance Agency (JQA) [77].

7.1.7 Centre for Cybernics Research (CCR)

The Centre for Cybernics Research was established as a result of a research project being adopted by FIRST, the "Funding Program for World-Leading Innovative R&D on Science and Technology" initiated by the Council for Science and Technology Policy. Under this programme the CCR collaborated with the University of Tsukuba, Osaka University and Cyberdyne, Inc. to promote the development and research of human assistive technologies. The Centre's principal investigator Prof. Yoshiyuki Sankai (University of Tsukuba) who is also the president of Cyberdyne, Inc. and his team focus their research on enabling the elderly and the physically challenged to live securely, safely and independently [78].

7.2 Universities

A considerable amount of research and development is done at Japanese universities and graduate schools which have their own robotics laboratories. The following table lists some of the major institutions that are active in the field of human assistant robotics.

Universities	
Chukyo University	Chuo University
Doshisha University	Ibaraki University
Japan Advanced Institute of Science and Technology (Jaist)	Kanazawa Institute of Technology
Kobe University	Kochi University of Technology
Kyushu Institute of Technology	Kyushu University
Mie University	Nagoya University
Osaka University	Ritsumeikan University
Saitama University	Tohoku University
Tokai University	Tokyo Metropolitan University
Tokyo University	Tokyo University of Science
University of Tsukuba	Waseda University

Table 10 - Japanese universities and graduate schools involved with human assistant robotics

7.3 Special zones and areas

Development and research zones play an important part in accelerating the implementation of robotics and the growth of its market. They not only serve as centres where industry, academia and the government can collaborate; they are also meant to attract global businesses.

7.3.1 Tsukuba International Strategic Zone (Tsukuba, Ibaraki prefecture)

The city of Tsukuba is one of the world's foremost science and technology cities and home to approximately 300 research facilities as well as over 20.000 public and private researchers. Since 2011 the Strategic Zone's area includes the entire city of Tsukuba, the Tsukuba-no-sato Industrial Park (Ryugasaki City) and several facilities in Tokai-mura and Ami-machi.

Among the eight projects planned "Project 2" refers to "Living with Personal Care Robots". Its main objectives are to launch a certification scheme in order to establish a safety verification system for personal care robots, to accelerate empirical studies and therefore enhance the global competitiveness of the related industry.

Milestones

- Empirical studies of personal care robots (2009–)
- Turning safety standards into international standards (2013)
- Operation of test facilities related to safety certification of robots (2014–)
- Full-scale market introduction (2015) [79]

7.3.2 Kanagawa prefecture and Robot Town Sagami

In 2013 the Japanese government designated Kanagawa Prefecture as a "Comprehensive Special Zone for Local Revitalisation". The prefectural government plans to make the region a centre for robot development, including collaborations between companies, universities and medical institutions. Large companies such as Toyota Motors and Fujisoft have already started to partner up with the prefecture's research resources to jointly develop assistant robotic

devices [80].

Located in Kanagawa prefecture is the Robot Town Sagami. It aims at promoting the implementation and the popularisation of robots for livelihood support and care, and therefore serves as a test environment for several assistant robotics devices. Its activities comprise:

- Supporting the relaxation of government regulations
- Supporting insurance coverage for nursing care robots to promote their proliferation among nursing care facilities
- Utilising collaborative research, expert opinions and test runs to make practical use of important projects
- General assistance concerning government subsidies
- Making use of deregulations and coordinating test facilities and monitoring to perform most suitable test runs
- Offering close facilities for testing prototypes in the initial stages of development
- Working out plans for preferential treatment (subsidies, tax reduction and loans with low interest rates) to attract more robotic companies[81]

7.3.3 Planned areas

Fukushima International Research Industrial City (Innovation Coast Plan) (Fukushima prefecture)

The planned establishment of the Fukushima International Research Industrial City, or "Innovation Coast", is not only meant to promote the development of robots, but to speed the return of the region's residents. The plan was approved in 2014 by the Abe Cabinet and involves several financial incentives to attract robot-related companies and research institutions. By expanding to the special zone they will be able to purchase land at a lower cost and be eligible for subsidies and tax breaks. Although the Innovation Coast Framework does not specifically target human assistant robotics the incentives offered will apply to all types of robotic development. Starting in fiscal year

2016, the first bases, the "Robot Testing Fields" and the "International Industry-Academia-Government Collaboration Facilities for Robots" will be developed [82], [83].

Cybernic City (Tsukuba, Ibaraki prefecture)

Cybernic City is the brainchild of Prof. Yoshiyuki Sankai (CEO of Cyberdyne, Inc.). He envisions a "city of robots" that not only relies on assistant robotics technologies, but develops them, tests them and puts them to actual use in society. Cyberdyne's plans for constructing Cybernic City comprise of among others building a hospital and several homes for the elderly equipped with assistant robotics technologies. To further foster the creation of new industries Cyberdyne plans to invite entrepreneurs from Japan and abroad. A provisional agreement to purchase land owned by Ibaraki Prefecture has been concluded at the end of 2015 [84].

8 Human assistant robotics in the EU and supporting programmes

Japan and Europe face the same societal challenges due to demographic changes. As the demand for care will increase with the ageing population, so will the costs considering the proportion of human caregivers decreasing over time. Just like Japan the European Union sees the application of robotics technology as part of the solution.

8.1 Horizon 2020

Horizon 2020 is the biggest EU Research and Innovative programme ever initiated with up to EUR 80 billion of funding that is available over 7 years (2014 to 2020). It is seen as a means to drive economic growth by fostering research and innovation especially in regard to excellent science, industrial leadership and tackling societal challenges. Funding opportunities are set out in multiannual work programmes. The current main work programme covers the period from 2016 to 2017.

Robotics has been identified as one of six main activity lines in the ICT-Leadership in Enabling and Industrial Technologies (LEIT) part of the Horizon 2020 work Programmes. Under Work Programme 2016 - 2017 the call for "*EU-Japan cooperation on Novel ICT Robotics based solutions for active and healthy ageing at home or in care facilities*" has been made in 2015. It addresses the support of older people in ordinary daily life at home and in care facilities as well as the extension of active and healthy ageing. Results shall be achieved by developing and demonstrating solutions that are based on advanced ICT Robotics (information and communication technology robotics). Applications can be submitted until 12 April 2016 (17:00:00). The designated Horizon 2020 National Contact Point (NCP) in Japan is the EU-Japan Centre for Industrial Cooperation.

In general Japanese parties are not automatically funded through Horizon 2020. They have to determine themselves the sources of funding for their part of the project, such as own funds or funds received from Japanese entities. Since the current call has been launched together with the Ministry of Internal Affairs and Communications (MIC) and the National Institute of Information and Communications Technology of Japan (NICT) two Japanese funding organisations are involved. Japanese partners may also request funding from the European Commission. However this is provided only in exceptional cases [85], [86].

8.2 Japan-EU Partnership in Innovation, Science and Technology (JEUPISTE)

JEUPISTE is a Japan-EU partnership programme that is funded by the EU through the Seventh Framework Programme FP7. It aims at the promotion, enhancement and development of Europe-Japan cooperation in Science, Technology and Innovation (STI) and runs from September 2013 to August 2016. Just like Horizon 2020, JEUPISTE focuses on key enabling technologies and societal challenges such as "ICT" and "Health, demographic change and well-being". Main activities comprise the support of policy dialogues, bilateral

dissemination, networking and twinning, as well as providing a helpdesk and training of experts. A consortium of 10 Japanese and European partners, including its coordinator, the EU-Japan Centre for Industrial Cooperation, executes the project [87].

8.3 European Interest Group (EIG) CONCERT-Japan (EIG CONCERT-Japan)

EIG CONCERT-Japan is an international joint initiative to support and enhance Europe-Japan STI cooperation in various fields. For this purpose the initiative implements funding for joint calls that aim at sustainable research cooperation between European and Japanese researchers. Main activities comprise enhancing inter-regional cooperation, developing opportunities for high quality research networking, establishing and maintaining partnerships, as well as exchanging and creating knowledge. Although previous and current calls have not considered human assistant robotics, yet, an opportunity for cooperation might arise in the future [88], [89].

8.4 Example project: Meaningful Technologies for Seniors (METESE)

In October 2015 the three-year collaboration of the Finnish VTT Technical Research Centre and AIST on METESE was initiated with the objective of jointly developing "*an integrated model for the elderly (home)care service design*" [90]. It brings together research institutes, care service providers and technology providers.

METESE specifically aims at the participation of the elderly and professional care givers in brainstorming, assessing and testing applications right from the start of the design process. The intended result is the development of ICT-supported service solutions and technologies that increase the quality of life, as well as support active aging, and enable living at home as long as possible [91].

9 Case studies

9.1 Japanese companies

9.1.1 Cyberdyne Inc. (CYBERDYNE 株式会社)

Cyberdyne Inc. is a robotics and technology company based in Tsukuba, Ibaraki prefecture that focuses on tackling and solving social issues by innovative technology. It is very well known for its Robot Suit HAL® (Hybrid Assistive Limb) series - wearable lower limb exoskeleton devices for medical and non-medical use. Since its foundation in 2004 Cyberdyne has made lots of efforts to facilitate the implementation of technology that coexists with people by thorough R&D, cooperation with national strategic zones, participating in creating standards etc.

The company's strong presence in Europe is represented by its four subsidiaries in Germany (Cyberdyne Care Robotics), in the Netherlands (Cyberdyne EU B.V.), in Denmark (Cyberdyne Denmark ApS) and in Sweden (Cyberdyne Sweden AB).

Achievements related to human assistant robotics:

- HAL for Medical Use, HAL for Labor Support and HAL for Care Support were certified in conformity with the European Machinery Directive, thus allowing the devices to be marked with the CE Marking and offered for sale in EU countries
- HAL for Medical Use is covered by worker's insurance in Germany
- Cyberdyne was awarded the ISO 13485 (Medical Device) certificate for robotic medical device manufacturing
- HAL for Labor Support and HAL for Care Support received the world-first ISO 13482: 2014 certification from the Japan Quality Association (JQA)
- Cyberdyne received the MHLW's approval to manufacture and sell HAL for Medical Use as a medical device [92]

9.1.2 Reif Co., Ltd. (リーフ株式会社)

Reif Co., Ltd. is a relatively young company that was founded only in 2008. Its products comprise the assist robot for walking rehabilitation "Soutenir" and the Bed Transport Assistance Robot that can be attached to hospital beds, wheelchairs and other heavy transportation devices. While the transport robot is still under development Soutenir has already been acknowledged as walking assistant robot (not registered as medical equipment) by the MHLW.

The initial idea behind the company's establishment was to find potential applications of their technology to benefit society. As a partner of a country-run project on Parkinson's, Reif started to apply their skills into this field and to work closer to the people. One approach was to talk to care personal and patients/ the elderly even before conducting research which now gives the company an advantage over competitors in terms of being able to address specific needs. Reif thereby specifically focuses on the decreasing number of active population and the ageing population [93][26].

9.2 European companies in Japan

9.2.1 ZORA Robotics

QBMT is a small Belgian company of 15 people (including 10 developers) that started to work with robots in 2012. After initial contacts with the French company Aldebaran Robotics QBMT decided to buy its NAO robots and to design the software that allows them to operate. The resulting robotics solution named ZORA (Zorg (Health), Ouderen (Elderly person), Revalidatie (Rehabilitation), Animatie (Animation)) was created, mainly to support nursing staff and to counteract the dire shortage of manpower in the care sector.

After two and a half years of development ZORA was introduced to several Flemish nursing homes on a trial basis. Meanwhile the robot is used in the Netherlands, Germany, France and Switzerland. Only recently, QBMT has

[26] Information gathered from interviews

signed a contract with ChartaCares, the health care business unit of ChartaCloud Technologies which will offer ZORA robots to U.S. skilled nursing facilities and retirement communities.

Business relations with a Japanese company opened up when QBMT was approached by Dai Nippon Printing (DNP) in 2015. The company is now looking closely into ways of distributing ZORA robots in Japan [94], [95], [96], [97], [98].

9.2.2 ReWalk Robotics Ltd.

ReWalk Robotics, which calls itself the leading exoskeleton manufacturer is one of the international key players in this sector. The Israeli company is designing, developing and commercialising exoskeletons that allow wheelchair-bound people to walk again. One of the currently offered systems can be used at home and is custom-fit for each user.

Besides the Israeli head office ReWalk Robotics has branches in the United States and Germany (ReWalk Robotics d.b.a. Argo Medical Technologies GmbH) where the company already received the respective clearances to market. The first individual cases of ReWalk systems being approved for reimbursement in Germany and the United States have already been announced.

In 2013 ReWalk Robotics additionally teamed up with YASKAWA Electric Corporation to distribute its exoskeletons not only in Japan but also in China, Singapore, Taiwan, Thailand and Korea [99].

10 Opportunities for European Companies

Some of the driving factors behind Japan's efforts to push the development of assistant robots also represent the biggest opportunities for European companies. Therefore knowing about the shortcomings of Japanese companies can pave the way for European success stories.

Europe faces the same population ageing as Japan

Although the whole world is looking at how Japan will use robots to solve its demographic and societal issues the very problem of a greying population is not unique to this nation. European countries face the same situation but at a slower pace and just like Japan they see a valuable potential in assistant robots to cope with it. The initial advantage European companies have is that they can learn from Japan, which is one of the fastest ageing countries worldwide, bring their own experiences to bear and utilise the best methods of both approaches.

Growth of demand

Since the gap between care recipients and caregivers in Japan is expected to grow further and other approaches to compensate for this disparity, such as a relaxation of Japan's immigration law, are not seriously taken into consideration the demand for human assistant robots will increase within the coming decades. The additional growing number of elderly people and people with dementia ensures a stable market.

Types of human assistant robots

The general target user groups comprising the elderly, patients and caregivers vary significantly in their respective needs. Depending on which of those needs a European company focuses on it might gain certain competitive advantages. For example, while home applicable companion robots are smaller and might not need to comply with specific safety standards their development and commercialisation could involve less time and costs compared to other more complex types of human assistant robots.

User/ consumer characteristics

Although even in Japan there has been scepticism and mistrust of technology in the beginning the Japanese are said to be more accepting of and open to the utilisation of robots for personal care. A more specific opportunity arises when focussing on Japanese women who not only outlive Japanese men but also are

highly likely to live alone at an older age. Being a female caregiver may additionally increase the need for robot-assisted support. European companies taking the particular needs of Japan's women into account might therefore benefit. However prior to targeting, the question if Japanese women are considered a target group for assistant robotics in Japan at all (and if not, why) should be answered.

Insurance coverage

Long-term care insurance is available for Japanese aged over 40 who are bed-ridden, demented or afflicted with rheumatoid arthritis, terminal cancer and cerebrovascular disorders. Coverage includes purchase and/ or rental of homecare equipment and amounts to 90% of the costs [100]. Since the number of bed-ridden, weak elderly and patients with dementia is expected to increase the number of people claiming such costs is equally likely to rise. Depending on the results of the Japanese government reviewing insurance coverage of human assistant robotics European companies might benefit from increases in demand due to reimbursement.

Further opportunities

Product testing

Although Japan is leading in terms of developing advanced robot technology it lacks the suitable environment for adequately testing it. The fact that Japanese companies have frequently made use of such environments in Western European countries and still do clearly underlines the value of test possibilities [52]. The expertise of European companies in focussing on user needs from the initial stages of development enables them to create robotics solutions that fit existing needs, unlike their Japanese counterparts.

Innovation

European SMEs are known to be extremely driven by innovation, whereas Japanese ones are said to be more pessimistic and risk-averse. According to an OECD study on innovation performance and policies of SMEs Japan is lagging

behind its peers in all surveyed aspects of innovation. A particular opportunity for European companies derives from this situation, as Japanese SMEs must internationalise because of the shrinking domestic market. Cooperation involving transfers of knowledge and experience might ease the market entrance both for European companies in Japan, as well as for Japanese companies in Europe [101], [102].

Lower business costs

A recent survey by JETRO found that the costs for foreign companies doing business in Japan are now lower than elsewhere in Asia. In 2013 "high costs" topped the list of obstacles among surveyed companies. This time it was ranked fifth. Especially office rents and housing costs for employees seem to decline relative to other major Asian cities, which supports investment [103].

11 Challenges for European Companies

Market entry does not come without challenges. In case of Japan the language has proven to be the biggest one. Other barriers might arise from the current market state, requirements and characteristics.

Infancy of the market

Although it has huge potential the Japanese market has just begun to grow, which is represented by limited demand, high prices and costs, ongoing regulatory discussions etc. Future developments and decisions will be essential to establish clear regulations, reduce costs, increase demand and widen the use of human assistant robots.

Standards and regulation

The first national standard for personal care robots, ISO 13482, has been established only recently and also national Japanese standards are still to be developed. That is why market growth at a higher pace had not been expected before 2015. As a consequence imports and exports to Japan might be affected. Moreover, since the regulatory environment in regard to applying laws and

labelling seems as yet unclear further obstacles might occur.

Long-term investment

Developing and manufacturing human assistant robots not only is capital-intensive but requires long-term investment, which usually has a deterrent effect on investors. They expect returns at a relatively early stage although robotics technologies may not yield profits for several years. The fact that Japanese firms face similar problems emphasises the difficulty of finding proper investment solutions.

Personnel

Although the Japanese labour market has opened up and Japanese people are more willing to work in smaller companies, such as SMEs, finding personnel can be difficult, particularly when people with special skills and knowledge of English are needed. In the context of human assistant robots even more problems can arise as qualified specialists are in high demand in Japan. When it comes to job offerings they are more likely to choose a domestic firm with an established name over an unfamiliar foreign company. Second, Japan lacks trained personnel and rules with regard to nursing care robots. There are seemingly few workers proficient at operating robots in that field which in the end might limit the number of customers (facilities).

Also European companies need to bear in mind that at some point they will have to transfer existing staff to Japan in order to establish first contacts and partnerships. Depending on the company's size this might become an issue[102], [104].

Trust

Consumer and user trust needs to be earned by European companies whose brand is yet to be established on the Japanese market. That requires long-term commitment, a reliable product and high quality standards (the Japanese

market is notable for its large need for high quality). Moreover, as nursing care is a very intimate and sensitive subject trust could be essential to market success. On the other hand, once it has been built up it might not only make the current customer generation available but also the following ones based on good experiences of family members.

12 Recommendations

How to make first contacts

Visiting exhibitions can be the first step to promote a company's product and portfolio, get to know potential competitors and make initial contacts with potential partners. Being a robot nation Japan annually and biannually hosts numerous trade fairs that centre around robotics and healthcare.

2016/ 2017 Tokyo-based exhibitions	
Medtec Japan: Care & Welfare Robot Expo	(20 to 22 April 2016)
International Modern Hospital Show	(13 to 15 July 2016)
CEATEC Japan	(04 to 07 October 2016)
Int. Home Care & Rehabilitation Exhibition	(12 to 14 October 2016)
Japan Robot Week	(19 to 21 October 2016, biannual)
HOSPEX	(26 to 28 October 2016)
International Robot Exhibition	(2017, biannual)

Table 11 - Tokyo-based trade fairs (2016/ 2017) involving robotics and healthcare

Although often titled "international", some of those fairs still lack internationality in terms of English-speaking Japanese exhibitors or even presentations. Enlisting a native translator's services should be taken into consideration depending on the seriousness of the visit.

How to enter the Japanese market

If European companies need assistance in establishing business contacts they may rely on the services and experiences of intermediaries. Consultancies, organisations and programmes specialising in technological and knowledge transfer can help companies adapt and market their products in Japan. The main advantage is a well-established local network that provides access to suitable partners, experienced bilingual staff and reputable experts. Organisations like JETRO even offer free temporary offices.

Organisations, programmes and consultancies	
EU-Japan Centre for Industrial Cooperation	http://www.eu-japan.gr.jp
EU Gateway Programme	https://www.eu-gateway.eu/
Enterprise Europe Network (EEN)	http://www.een-japan.eu/
Executive Training Programme (ETP)	http://www.eu-japan.eu/business-programmes
Japan External Trade Organisation (JETRO)	https://www.jetro.go.jp/en/

Table 12 - Organisations, programmes and consultancies offering assistance in EU-Japan business

Companies that have no experience in doing business in Japan are recommended to cooperate with local partners.

Specific recommendations

Avoiding priority areas

Current governmental funding schemes specifically target five selected priority areas (transfer aids, mobility aids, toileting aids, monitoring systems and bathing aids) most likely resulting in an increased level of competition in those fields. European companies should try to focus on different areas, if possible (companion robots, tele-care robots, robots for assistance in daily life etc.).

Maintaining a proper development focus

Japanese companies show the tendency of putting more effort into research and development than in the market deployment of their assistant robotic technologies. Companies of European countries that share the burden of high

costs of nursing care and nursing staff instead should show a keen interest in a rapid implementation into care facilities and homes. Focusing at an early stage on a functioning end product that is ready for use might provide at least time advantages. This includes the avoidance of over-engineering, that is adding functions as much as necessary, but as little as possible.

Using established platforms or current technologies

European companies who seek to enter the Japanese market for human assistant robotics might rely on current technology solutions or already established robotic platforms, such as the Aldebaran NAO or Pepper robot. As shown before, there is potential for software developers. On the other hand, technological solutions like tele-care robots designed for consumers might provide advantages, as their development involves fewer costs due to advances in mobile technology (there is mass-market access to voice and video over IP, touch screen interfaces, voice and facial recognition, and gestural interfaces)[24].

13 Concluding Summary

Being not yet mature, the Japanese market for human assistant robotics bears an immense potential for growth on several levels. First, the increasing number of elderly people and dementia patients as well as the widening gap between care recipients and care givers guarantee for a stable and growing demand. In terms of figures, within the short period of 20 years between 2015 and 2035 its sales value will be likely to increase geometrically (58X) from JPY 24.1 billion to JPY 1.4 trillion including robots for nursing care, physical support and monitoring. Meanwhile, the infancy of the market comes with a number challenges that need to be kept in mind, which include: limited demand, high prices and costs, as well as ongoing regulatory discussions concerning standards, labelling and insurance coverage.

Secondly, although already highly established in Japan the market for RoboTech (robot technology) is expected to show a further noticeable increase up to JPY 1.56 trillion by 2035, possibly offering entrance opportunities for European companies.

Thirdly, the software market might be of interest, as Japan is said to be a manufacturing nation without taking a lead in this specific area.

More particular opportunities arise from the fact that Europe and Japan face the same problem of a rapidly ageing population and can learn from each other's approaches to cope with it. European companies should also be aware of, and use to their advantage, specific aspects of the robotics market in Japan such as the lack of user involvement in the development process and the focus on manufacturing rather than commercialisation.

14 Table of Figures

15 List of Abbreviations

AIST	National Institute of Advanced Industrial Science and Technology
ATR	Advanced Telecommunications Research Institute International
DBJ	Development Bank of Japan
ISO	International Organisation for Standardisation
JARA	Japan Robot Association
JARI	Japan Automobile Research Institute
JETRO	Japan External Trade Organisation
JEUPISTE	Japan-EU Partnership in Innovation, Science and Technology
METI	Ministry of Economy, Trade and Industry
MHLW	Ministry of Health, Labour and Welfare
NEDO	New Energy and Industrial Technology Development Organisation
OECD	Organisation for Economic Co-operation and Development

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