Information and Communication Technologies for Health, Demographic Change and Wellbeing:

A Survey of the Technological Scenario

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1. Introduction

A broad group of ICT (Information and Communication Technologies) are currently emerging for health care and monitoring (prevention, treatment, assistance and rehabilitation), as well as for occupational and recreational support of ageing population in response to changing demographics and health needs in the EU (Fig. 1).

![Worldwide today:](source: World Health Organization)

- 1 billion adults overweight
- 860 million individuals with chronic conditions
- 600 million individuals age 60 or older
- 75-85% of healthcare spending is on chronic condition management

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**Fig. 1 Schematic of ICT-based support for ageing population (source World Health Organization)**

On one hand ICT holds a huge potential for management and delivery of health and social care to an ageing society and offers increasing opportunities for independent living of elderly. On the other hand, there is a growing concern about the possibility that these technologies, like other innovations, could be contested by societal actors because of ethical issues or because of their inadequacy to properly meet societal needs and expectations. This could ultimately bring to a strong limitation in their market perspectives.

To overcome these problems, the European Commission has recently launched a number of initiatives falling under the umbrella of Responsible Research and Innovation (RRI), an inclusive approach involving all stakeholders in the research and innovation (R&I) processes to achieve a better alignment of innovative products/services with societal needs [Ref. 3].

In this context, the Responsible Industry Project¹ specifically aims to integrate principles and methodologies of RRI into the research and innovation processes developed by industries active

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¹ [http://www.responsible-industry.eu/](http://www.responsible-industry.eu/)
in the domain of ICT for Health Demographic change and Well Being. The ultimate objective will be the development of an “Exemplar Implementation Plan for RRI in Industry” pursued through several activities, including pilot projects and case studies.

To achieve maximum impact, it is then helpful for all involved actors to have a good knowledge of the technological scenario in which principles and methodologies of RRI will be introduced and tested. To this purpose, in the following we will examine in detail the characteristics of the enabling technologies developed or under development to provide AAL (Active and Assisted Living) products/services. This will allow to appraise which aspects could arise ethical concern, in particular when these technologies are used (alone or combined together) to provide solutions for the ageing population. Several significant examples of the main applications will be derived from the Projects developed in the framework of the AAL Joint Programme\(^2\) funded by EC with the objective to enhance the QoL (Quality of Life) of older people.

The last part of this Report will be devoted to a market analysis for AAL technologies. It examines how the actual barriers to market deployment for the ICT for an ageing society could be lowered if these technologies would better answer to the needs and expectations of the end users through their involvement in the innovation process.

2. Enabling Technologies for AAL (Active and Assisted Living) solutions.

The Coordination Action AALIANCE\(^3\) has recently recognized three complementary and partially overlapping “pillars” that characterize a person’s life and in particular in elderly (Fig.2): Prevention, Compensation & Support, Independent & Active Ageing [Ref. 1-2]. ICT can be applied to all three of them, raising the capacity of the person to increase the years of healthy life and activity.

- **Prevention** can be applied throughout the whole life of a person, but it is particularly important for old people, since it allows them to have more years of healthy life and better manage already existing disease. It can be defined as \(^1\)“action to reduce or eliminate the onset, causes, complications or recurrence of disease”.

- **Compensation and Support** concern elderly people with physical or cognitive impairment that need help with the daily activities.

- **Independent and Active Ageing** refers to the possibility for old people to keep on living on their own, participating to the social activities and, when wanted, working.

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\(^3\) AALIANCE (http://aalliance2.eu/) is a Coordination Action funded by EC within the FP7 Programme “Cooperation” to promote Ambient Assisted Living (AAL) solutions based on advanced ICT technologies for ageing and wellbeing of older persons in Europe. AALIANCE2 has been built upon AALIANCE Innovation platform (2008-2010).
Fig. 2. The three pillars recognized by AALIANCE2 Roadmap [1-2]: Prevention, Compensation and Support, and Independent and Active Ageing

AAL (acronym for Active and Assisted Living, formerly Ambient Assisted Living) is the label commonly used for Information and Communication Technologies (ICT) developed to assist people to ageing well at home, in the community and “at work”.

There are different ways of categorising ICT tools and interventions that may address different aspects of this grand challenge. On a broad level one can distinguish between:

- **Assistive Technologies** (examples of which include support and compensatory technologies for visual and hearing impairments; technologies for improving mobility and autonomy, localization and orientation support; support systems for object manipulation and service robotics; systems and IT solutions for intelligent environments and smart homes);

- **Technologies for Physical Prevention** (examples of which include exercising and training systems that take into account the physical condition of elderly people; systems to measure and assess physical conditions, wrong postures e.g. advisory systems; systems that take into account both physical and cognitive condition to optimize the training outcome);

- **Technologies for Rehabilitation** (examples of which include rehabilitation robotics and functional electrical stimulation for physical training and motor learning; tools to quantitatively assess functional improvements in neurological patients; methods to assess cognitive and motor learning and training related neuronal changes; low cost technologies that enable rehabilitation in out-patient facilities and at home).

The ICT systems which provide AAL services are typically comprised of sensors (sensing components), of parts that process the sensor data and derive conclusions (reasoning components).
components), of human-machine interface (interacting) components and actuators that execute actions started by the system such as switching the light, or raising an alarm in case of an emergency (acting components). Finally, the different system components need to communicate with each other in order to provide the overall assistive service for which the system has been designed [1-2].

In the following, the characteristics of these different components (enabling technologies) will be described in detail and the potential ethical concerns arising from the use of these technologies will be outlined.

2.1. Technical Components for Sensing

A sensor is a device or system which measures a physical, chemical, electrical, or optical quantity of a phenomenon and produces an output related to that quantity. A sensor is composed of a fundamental transduction mechanism (sensing element), that converts one form of energy into another, and an output interface, including a physical packaging, conditioning electronics and external connections (e.g. electrical or optical).

A sensor with built-in processing and embedded with a network interface is usually called “smart” sensor and needs a power source to be operated. These smart sensors will progress, in terms of cost, power consumption and functionality, at rates similar to those experienced by other integrated circuits, such as microprocessors and memory, because they use much of the same technology.

2.1.1. Types of sensors.

Sensors for telehealth and telecare applications fall into three main categories: wearable, implantable and environmental sensors.

Wearable sensors are common today with most coming from the mobile phone and the wellness industries. These sensors are focused on location and movement. MEMS-based sensors (accelerometers, gyroscopes, magnetometers, and physiological or biometric sensors), worn on different parts of the body, are used for recognition of activities as walking, running and climbing up stairs, or physiological parameters (Fig. 3).

*Fig. 3 Wearable Sensors for Health Monitoring* [4]
Also textile sensors are becoming an interesting promise for daily monitoring of vital signals: they could be integrated in smart shirt with both physiological ECG and physical activity detectable sensors to improve the accuracy of the patient diagnosis.

**Implantable sensors** are for example accelerometers implanted under the skin for monitoring and processing of heart vibrations (to prevent heart attack). Safety of implantable sensors is a critical issue raising concern for health.

**Environmental sensors** include the development of new families of contactless sensors, such as 3D image sensors for surveillance and reconnaissance applications

### 2.1.2. Micro-Electro-Mechanical Systems (MEMS)

Future sensor technology strongly relies on the development of Micro-Electro-Mechanical Systems, or MEMS, to integrate microsensors, microelectronics and other technologies onto a single microchip. MEMS are miniaturized mechanical and electro-mechanical elements (i.e., devices and structures), made using the techniques of microfabrication (dimensions of MEMS devices can vary from well below one micron to several millimetres).

The MEMS devices can vary from simple structures having no moving elements, to extremely complex electromechanical systems with multiple moving elements under the control of integrated microelectronics\(^5\).

![Fig. 4 MEMS & Sensors for Tele-health \(^5\)](image-url)
Functional elements of MEMS are miniaturized structures, microsensors, microactuators, and microelectronics. Microsensors and microactuators are categorized as “transducers”, i.e. devices that convert energy from one form to another. In the case of microsensors, the device typically converts a measured mechanical signal into an electrical signal. MEMS devices like accelerometers, gyroscopes and microphones, can be integrated into today’s smart phones.

MEMS devices are not specifically developed for AAL systems, but their use is extended to AAL. As MEMS and sensors for AAL evolve, it is likely that the clinical/non-clinical and life critical/non-critical issues will be managed together. Information will be collected by a number of disparate sensors, aggregated by different hubs and shared to create holistic views of the individual, his or her surroundings and the interactions between people and things. This will result in a huge amount of personal data to be handled in an accountable way.

It can be asserted that both the safety of implantable sensors and the personal data protection are the most critical issues related to the widespread use of sensing technologies and need to be addressed in the framework of RRI initiatives.

2.2. Technical Components for Reasoning

If we compare AAL systems to a human body with its sensing organs (e.g. eyes and ears), communication abilities and acting by movements caused by controlled muscle activity, then the brain would be the reasoning and control structure. This paragraph shortly describes the expected evolution of artificial “brains” inside AAL systems for the forthcoming years [1-2].

In information technology (IT) a reasoning system is “any software application, hardware device or combination of software and hardware whose computational function is to generate conclusions from available knowledge using logical techniques of deduction, induction or other forms of reasoning”. (Wikipedia, 2013).

In the context of AAL, reasoning is defined as [1-2]: “aggregating, processing and analysing data and transforming it into knowledge”.

Reasoning systems could be implemented on a dedicated device together with one or more sensors, on an on-body device for mobile situations, on a home device, or on a server that is connected to a network [2]. They apply a wide variety of approaches with complexities ranging from low to high (as in the case of statistical methods, artificial neural networks and methods of the semantic web). Futuristic attempts include the creation of a human-like artificial mind that could be embodied in a social service robot.

Some of today’s simplest tele-health systems measure vital parameters of their users such as their glucose levels, body weights, respiration rates or heart rates. Reasoning modules in these systems use simple algorithms in order to detect or to predict emergency situations like falls and near-falls, acute heart problems, or extreme changes in the blood pressure. More sophisticated models and methods, on the other side, learn from given data and generalize from it in order to
classify, detect, predict or cluster new data sets, even if they are incomplete or uncertain. These machine learning approaches have many applications in AAL. One important application field is the classification of data obtained by sensors that might be worn by the user or installed in the environment as accelerometers, sensors in home appliances like refrigerator doors, infrared presence detectors, pressure sensors in bed and on chairs, light switches and the use of electrical devices, TV sets, doors of wardrobes and drawers of cupboards.

Other variables that describe the status of end-users and that are analysed by reasoning systems concern their motion habits by analysing data about the occupancy of rooms in a flat, locomotion data (e.g. walking, standing, sitting, lying, falling) and quality and quantity of motion (walking speed, walking distance, duration of physical activity, motion patterns etc.).

Other machine learning models are applied to video processing, voice and gesture recognition, image processing. Furthermore, trend analysis can give insights into the changes over a longer time period of a person’s psychosocial behaviour and social contacts, and mental and psychical constitution including stress and emotional states. This information can be extrapolated and analysed by professional care givers, psychologists or medical doctors to detect anomalies in the activity pattern of AAL users that might require to draw the attention of caregivers or family members onto a potential problem.

Assistive technologies can help relatives of older people with cognitive impairment by providing assurance that the elder is safe and is performing necessary daily activities, and, if not, alerting the family or a caregiver; by assisting the elder in the performance of her/his daily activities and by assessing her/his cognitive status. Associative memories help people with increasing cognitive impairments to remember facts they knew in their past. A similar approach is applied by reminders for medicine intake.

Coaching applications (so far mostly designed in research projects and to a lesser extent available on the market) for health related topics or diet issues, help users through personalized instructions, tips and tricks, do’s and don’t’s to treat and to prevent diseases and to obtain a better QoL.

Decision Support Systems should provide to the different groups of end-users, i.e. older people, formal and informal caregivers, medical professionals, knowledge-based support in different situations from emergencies to prevention of diseases through a healthy lifestyle.

An issue that has to be carefully considered in this technological context is the provision of data security and data protection of the knowledge about people, especially if the data are interpretable by humans. The highest risk is perceived for limitation of the individual rights and liberties (like privacy, rights to freedom of movements, autonomy, etc.).

2.3. Technical Components for Acting

Systems and services, which proactively act for health care and monitoring (prevention, treatment, assistance and rehabilitation), as well as for increasing the independent living of senior persons or disable people in an assisted environment, revolve around some technological
aspects, that could be identified as *acting enabling technologies*. More appropriately, these are sensor-motors, actuators and other agents that could perform concrete actions basing on their perception of the environment, on behalf and emotion of their users and on information gathered by some other device and/or background knowledge (Fig. 5). These technologies fall in the field of *robotics*.

Actuation is defined as automatic control through actuators, feedback (e.g. information, suggestions, guidance) local or remote (e.g. call centre), instantaneous (e.g. in the case of alarms) or delayed (e.g. in the case of trend information and lifestyle recommendations), to relevant participants using personalized interfaces.

![Fig. 5 Artificial hand](image)

Actually most of the research is focused on the development of smart actuators inspired by mechanical characteristics of human actuators: *muscles*. For this reason this type of actuators are commonly called artificial muscles.

In the future, a new class of machines and linked technologies will be required in order to maintain the current QoL of the population. These new generation of robots will be the Robot Companions (RCs) for Citizens, i.e. machines that will primarily help and assist elderly people in daily activities at home, in their workplace and in other environments. RCs will be able to perform a multitude of roles thanks to their capabilities to act and interact physically, emotionally, socially and safely with humans, providing for an improved QoL.

These assistive social robots, designed for social interaction with humans, could play an important role with respect to the health and psychological well-being of the elderly. RCs should have soothing features, to not frighten humans. To this purpose, scientists try to render robot physical body much more similar to human body. If we want robots with a more adaptive and complex behaviour, however, it will be necessary to increase the number of degrees of freedom, the number of sensors, the computational load, the energy consumption and the signal transmission rate of the human-machine interface. Moreover, what is required in the next future is a network system that manages various types of robots and other agents. Fig. 6 reports the main technological challenges which have to be explored in the field of robotics in order to reach the next level of AAL services.
As regarding the creation of a pervasive and sustainable network, built around citizen necessities, smart city and cloud robotics could represent the future trend in this sense. Cloud robotics is the fusion of cloud computing and Robots.

Several research group are exploring the idea of robots that rely on cloud computing infrastructure to access vast amounts of processing power and data. This approach would allow robots to improve their skills in order to better accomplish their tasks. Cloud Robots will really help humans (in particular elderly persons and people with disabilities) by replacing them on those tasks that are more dangerous, delicate, precise, tedious, etc.

![Fig. 6 Technological challenges in the field of robotics (Source: AALIANCE2 Roadmap)](image)

Trust and security issues represent a major concern in cloud robotics. In fact, in this approach a robot would need to launch tasks on a public cloud. Moreover, confidential data could be stored in the public cloud storage. Therefore, strong integrity and confidentiality protection are needed to secure privacy sensitive data.
2.4. Technical Components for Interacting.

Human-machine-interaction is one of the most important aspects for design, development and market acceptance of AAL technologies and products. If a robot takes a glass of water, offers the glass to the user– perhaps accompanied with an acoustical or visual signal – and waits that the glass will be taken from the user, this is human-machine interaction.

Interacting is a key success factor for Ambient Assisted Living technologies in order to address the usefulness of devices and components to the users – which are the private customers at the end of the value chain as well as professional users, e.g. care providers, medical experts, relatives, friends or others.

Appropriate interface technologies are needed to enable successful human-machine-interactions and to satisfy specific requirements in order to cope with the abilities of users. In particular, interacting with AAL technologies should be as much “natural” as possible, i.e. with as low effort from the user. Good examples are touch screens that have been successfully developed for everyone’s use for gesture input on Smartphones, tablet PCs or stationary displays.

Natural user interfaces (NUI’s) could use speech for input (speech recognition) and output (natural or synthetic speech), handling and movement of control devices (e.g. joystick, mouse) or touching on a certain point on a 2D surface (touch screen) or making specific signs or movements in a 3D space (gesture based interaction to control services without touching the device).

Another big challenge is that the system is able to recognize a sequence of words or actions of the user and to interpret the meaning of the situation or the intention of the user in the actual context.

Finally, interfaces for AAL systems should be utilizable at any place: at home, on the move, in the car or at public buses or trains.

2.5. Technical Components for Communicating.

The topic of “communicating” is one of the five enabling technologies for AAL. Here, “communicating” does not relate to communication between humans, or human-machine-interfaces (both of which are covered under “interacting”), but the communication between systems and system components, i.e. “machine-to-machine” communication (Fig. 7).

Communication networks (both wired and wireless) and communication protocols are the key issue of communicating, which also brings in the topics of communication standards, and the interoperability between systems and system components (i.e., the ability to correctly understand and process the information exchanged over the system interfaces and thus the ability of the components to collaborate in performing the service desired by the user).
Transmission of data from sensors generally rely on a network architecture known as the **Body Area Network** (BAN) \[^7\]. BANs enable wireless communication *in or around* a human body in three different tiers [Fig.8]:

- **Intra-BAN communications** refer to communications between body sensors and/or between sensors and a central gateway (often a smartphone).
- The **inter-BAN communications** include communicating data from personal devices such as smart phones to the access points;
- The **beyond-BAN tier** connects the access points to the internet and other networks.
One of the most important applications of Intra-Ban is the monitoring of vital parameters (e.g. pulse, body temperature or ECG). Since Intra-Ban and Inter-Ban communications often contain medical data, which must be considered sensitive in nature, security and safety of these networks are an important issue.

Inter-BAN communication relies on home networks or LAN (Local Area Networks) that are used also for the home automation domain. In this case, protection from unauthorized access and use is of prime importance in particular where actions can be initiated over the network, e.g. to switch on or off certain devices in the home, or lock/unlock doors or windows, since malicious use could create significant financial (e.g. burglary) or physical (e.g. fire) damage. Not all wireless home automation protocols provide appropriate protection from such attacks, and for other protocols such protection must be explicitly enabled at installation time since components come with “security deactivated” by default.

Finally, Wide Area Networks (WAN) are used for whenever an AAL system needs to transmit information to the “outside world” (as in the case of “beyond-BAN communication”). For connections from the home environment this is most often an Internet connection today, where a number of different access technologies are offered by providers, based on the telephony cable infrastructure, TV cables, mobile phones or satellites. In addition to the price, the speed and reliability (availability) of the connection are the most important selection criteria.

2.6. Technological challenges

There are still several challenges in the domain of AAL solutions for health, rehabilitation and care. The following list presents a number of them [1-2]:

- Integration aspects.
  - Interoperability: this relates to standardization of data models, protocols, message formats, and vocabularies to enable meaningful exchange of data between services.
  - Dynamic configuration of services, within the home or around the person (taking into account the joining and leaving of devices and the paring of devices) as well as back-end services.
- Video communication evolving from low resolution to high resolution.
- Security and privacy in an environment covering home, the person’s immediate environment, the wide area network and the back-end services.
- Bandwidth availability.
- Robustness and fall-back in case of problems.
- Power management and low-power sensors and actuators.
- New type of sensors, e.g. related to bio-markers.
- Reasoning systems on all available data, e.g. for decision support.
- Advanced algorithms, e.g. related to neuro control and smart sensors.
- User interaction for clients as well as care givers.

The capability to give a positive answer to these challenges is of paramount importance to foster the successful employment of ICT-based solutions in the domain of AAL.
3. Main Application Areas of ICT-based solutions for AAL

In the previous paragraph the enabling technologies for AAL (Active and Assisted Living) were presented, here the main application areas will be shortly described. Examples of applications are derived from the Projects developed in the framework of the AAL Joint Programme [Ref. 9] funded by EC with the objective to enhance the quality of life of older people and strengthen the industrial base in Europe through the use of Information and Communication Technologies (ICT).

- **ICT based solutions for Prevention and Management of Chronic Conditions of Elderly People**

This application domain comprises individualized home therapies and new care models leading to a better quality of life for people suffering from chronic diseases, aiming to prevent re-hospitalization.

**Home therapies.** Wearable sensors, advanced signal processing techniques and networking are technologies that can be applied to monitor the physiological parameters of patients and control their health, but not in an invasive manner (Fig 9).

![Scheme of the system developed by the Health at Home Project (H@H) to solve societal problems related to healthcare services for elderly citizens affected by Chronic Heart Failure (CHF), by enabling remote self-management of the patients and connecting in-hospital care of the acute syndrome with out-of-hospital follow-up.](http://www.aaleurope.eu/projects/healthhome)

This information must be provided remotely to users, their families and clinicians in order to make known constantly the health condition of the subject, to make an exact diagnosis, to

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4See more on the *Health at Home project (H@H)* at [http://www.aaleurope.eu/projects/healthhome](http://www.aaleurope.eu/projects/healthhome).
identify the correct therapies and to intervene at the right time. The combination of wearable or implantable multi-sensor platforms with sensors mounted in the environment, using low-power and reliable technologies, is being explored and the first prototypes are now being developed. Thanks to new low-power wireless technologies, low-bandwidth networks can be used for the exchange of data. Fixed and wearable sensors can provide information that can trigger messages at an appropriate time, and a mobile device can allow a message to be delivered to the appropriate context (families, clinicians etc.).

**Memory services.** Smart dispensers can remind users of the times to take drugs, also including the correct doses. The systems can also recognize when the medicines are running out and alert patients, their families and clinicians. Eventually such a service could be integrated into a disease management service to link the treatment to results measured by tele-monitoring.

**Rehabilitation services.** Patients can autonomously perform their rehabilitation exercises at home but can be remotely monitored by medical staff. The solutions in this area vary from sensor based systems that monitor the movements of a person to systems that give active support in performing the exercises using robotic like devices in case of neuro-rehabilitation.

- **ICT based solutions for Advancement of Social Interaction of Elderly**

**Social interaction and communication** are two elements that strongly influence the quality of life of elderly people. Technological applications can help people with physical and/or cognitive problems to communicate and to socialize with others (Fig. 10) by:

- Providing services that support users in communicating with members of their family, friends and clinicians.

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*Fig. 10 The Project ConnectedVitality (CVN)*[^1] develops a Personal Telepresence Network to link groups of senior citizens into a video communication network, enabling them to choose the activity as well as levels of social interaction (with family and friends) according to their individual needs, abilities and lifestyle. Links are provided also with care professionals.

[^1]: See more on the Project ConnectedVitality at: http://www.aal-europe.eu/projects/cvn
- Organising help from informal care givers, for example developing a list of informal care givers which fit specific needs
- Making it possible for people with disabilities to interact with other subjects while remaining at home.
- Helping people with a disability to join in activities carried out in recreational centres, houses of friends, cinemas, restaurants, theatres, churches, etc.

Sports and hobbies are a means of social interaction with other people. Older and disabled people often have difficulties in carrying out this kind of activities because of sensory, cognitive or motor deficiencies.

![Image](image1)

**Fig. 11** The platform developed by the Silver-game Project\(^6\) is an integrated solution which combines sensor-controlled gaming, web-based information services and interactive entertainment.

Solutions of ambient intelligence have the potential of keeping fit older people with the help of integration of ICT technologies (Fig. 11). Game-like applications and play-service concepts can be solutions that stimulate people to practise physical exercise. Examples of exer-gaming are dance games, camera-controlled games, simulator games, and location-information mobile games. Even small amounts of daily physical activity can strengthen a sense of good physical health. Physical exercise affects positively also mental health.

Interactive, stimulating and social-play environment are planned for children and their grandparents to play together. The goal is to combine elements of traditional playground, modern technology, and innovative and interactive applications.

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\(^6\) See more on the Project Siver-game at: http://www.aal-europe.eu/projects/silver-game
• **ICT-based Solutions for Advancement of Older Persons’ Independence**

Staying well and comfortable, and feeling safe and secure at home is an important aspect of life, especially for older people. It is therefore crucial to enable and extend autonomous daily living in a person’s own home when that person reaches an advanced age. Technologies may offer an enhanced sense of security, prolonged independence and an improved perceived quality of life for seniors (Fig. 12).

![A connected service system which will support a variety of assisted living solutions](image)

**Fig. 12** The Project Inclusion Society⁷ develops a connected service system which will provide preventive health care for senior citizens at home, improving their security and quality of life. The aim is to help people to adapt their lifestyle, improve their health, and feel connected. The client uses a tablet PC & records health data via smart sensors. Social interaction with family, friends & care provider is supported by a network of cloud ‘portals’.

Special attention must be paid to the integration of solutions and components that are already available on the market into a coherent and inclusive system, easy to use for those living at home.

Moreover, innovative solutions for dealing with emergencies in the home are needed. For example, “intelligent” clothing might be a tool to detect an emergency when the user is not within reach of stationary sensors and/or is not able to activate an emergency call. This clothing contains a sensor-system that will detect an emergency on the basis of missing or abnormal

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⁷ See more on the Project Inclusion Society at: http://www.aal-europe.eu/projects/ins/
value of physiological parameters of the user. It also contains a RF transceiver to automatically call an emergency service.

A combination of monitoring vital parameters of the person living at home, observation of the person’s activity, as well as monitoring the devices of potential sources of danger can lead to improved ambient assistance and personal safety. Technical solutions should be adapted to individual requirements, personal preferences and habits.

Ease of use, privacy, data integrity and reliability of sensors and systems are essential for acceptance of these systems. All these objectives are targeted by the RRI approach through inclusion of the general public in all stages of the innovation processes.

• ICT based solutions for Advancement of Older Persons’ Mobility

During their life persons might suffer from impairments and disabilities and often these deficits increase with age. The impairments can derive from a diversity of problems: vision, hearing, and motor abilities. Besides these physical impairments there are of course also mental or cognitive ones. Systems can be designed to enhance the residual capacity while in case of total absence of ability, alternative sensory abilities should be used (e.g. speech to text or text to speech).

Motor disabilities invalidate the ability to carry out certain tasks, this can limit the capacity of operating devices, manipulating objects and mobility. Bio-robotic solutions can represent a key technology to improve the quality of life of older people with motor disabilities.

Sensory impairments, e.g. of eye and ear, can have a high impact on the communication abilities of persons especially if the impairments start at an older age. Activities for improvement in this area should focus on interaction modalities that enhance the users abilities with regard to hearing, vision and speech, i.e. system advances aiming for a compensation of respective individual limitations.

Activities aimed at improving the mobility of the elderly can make public transport more accessible by providing the right information for moving around a city by public transport, by presenting this information taking into account the special requirements of the elderly on hearing, vision and speech, for example providing the means of finding the way through a city using a GPS-based system (see Fig. 13).

Several supporting ICT-based functionalities for individual mobility can be identified:

• Localization/positioning/navigation (outdoors, by satellite technology, currently GPS, combined with a suitable receiving device; indoor positioning/navigation through wireless technology);

• Digital maps for pedestrians;

• Near-field communications (NFC): an existing phone can be used to link to another device for different functions: to download tickets and/or to access railway stations by simply
touched the phone onto an NFC-enabled ticket barrier, to obtain audible information through a phone speaker, by touching the mobile adjacent to an NFC-enabled sign etc...

- Wearable sensors, e.g. accelerometers and pedometers, are also available for pedestrians.

**Fig. 13 Scheme of the solutions designed by the e-mosion Project 8 to enable integral outdoor and indoor localization and mobility services for elderly people with age-related sensory (visual, auditory) and cognitive (memory) impairments.**

Additional functionalities like verbal communication with information systems, smart cards, personalized multimodal systems etc. are also addressed in the context of other AAL applications.

It should be underlined that real-time monitoring of the user lifestyle and movements is considered as one of the ICT applications that raises higher ethical concern and should be addressed in the framework of RRI.

- **ICT-based Solutions for (Self-) Management of Daily Life Activities of Older Adults at Home**

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8 See more on the AAL e-mosion Project at: http://www.aal-europe.eu/projects/e-mosion
An important objective for persons with impairments and disabilities is performing the daily tasks. They need either support from other persons (family or care givers) or an automated support, i.e smart tools, such as robots (Fig. 14).

![Robot](image)

**Fig. 14** The project Adaptable Ambient Living ASsistant (ALIAS)² has developed a mobile robot system that interacts with elderly users, monitors and provides cognitive assistance in daily life, and promotes social inclusion by creating connections to people and events in the wider world.

Easy interaction between humans and robots is one of the most relevant aspects in this context and interfaces assume a critical role. Assistant/companion robots should be designed for supporting users in simple activities of daily living (taking drugs, dressing and undressing, personal hygiene, etc...) and for working in complex environments.

Other activities that must be carried out to satisfy daily needs of elderly include shopping for food, clothes, etc. and the preparation of meals. These activities are strongly related to the personality and autonomy of the subject.

To maintain this capability to elderly and to people who are not self-sufficient, the following services should be provided by ICT-based services (Fig. 15):

**E-shopping services.** Development of a catalogue/database of some shops of an urban network (or in a rural context) that can be accessed using a tablet computer or a standard PC or even a network connected TV. Personal information should be protected from external interference. It must be possible for the user to verify the presence of the items and their costs in reliable shops and to identify the shops where the products are sold at cheaper prices. The last step is the possibility for the users to send their order to shops and receive confirmation or refusal of their request.

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² See more on the Project ALIAS at: http://www.aal-europe.eu/projects/alias
**Services for the preparation of meals.** In many cases, preparation of the meal is a complex and dangerous activity to carry out for elderly people. Two solutions can be envisaged: delivering the meal directly to the user's home or using pots, pans or stove with sensors for cooking.

- Meals delivery service can be provided by connecting restaurants and canteens in a virtual network. People at home can look up meals in the database and can order the food they choose.

- Smart cookers, lids and pots and pans, with sensors, can control the cooking and baking of meals and, whenever necessary, alert the user to potentially dangerous conditions (e.g. foods burning, the flames on cookers needing to be extinguished, the cooker being switched on but with no pan on it, an inadequate quantity of water, etc...).

**Fig.15 The EDLAH Project**\(^{10}\) develops an easy to use platform that provides the older person with a greater level of independence by offering: immediate contact to loved ones, peers, emergency services etc...; assistance in the functional elements of life such as medication reminders, 'lost' object retrieval, dietary information, care recording, care tips etc...; transmission of health information to professional caretakers (via health indicators and trends available through the same service).

**ICT-based Solutions for Supporting Occupation in Life of Older Adults**

Demographic change, increase in average life expectancy and lower birth rates in Europe have important consequences for the supply of labor. The European Union has already adopted some initiatives to delay the age at which workers leave the labor market and to increase the employment rate of older workers. A supplementary strategy is to valorize voluntary work. In fact, the importance of active participation in life for people is not only related to their earning

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\(^{10}\) See more on the EDLAH Project at: http://www.aal-europe.eu/projects/edlah.
money but also to the expression of their own personality which can be manifested in voluntary work.

It is fundamental to guarantee the right to work to all people, not only to healthy persons but also to the elderly and people with disabilities. AAL solutions could be adopted to help individuals with disabilities to work and elderly people to extend their employment (Fig. 16). In principle, AAL solutions could:

- **Facilitate access to the working space.**
  The working environment should be designed to be accessible by individuals with motor deficiencies and who need assistive aids to move (e.g. a stick or wheelchair).

- **Assure the right working conditions related to the environment, and the personal situations and capabilities.**

For example, smart working environments (SWEs) should have sensors that measure ambient parameters, such as temperature and humidity, and, according to the measured data, vary the air-conditioning to respect optimal parameters.

*Fig. 16 AWARE project aims at developing technological tools, designed under needs and requirements of the final users, to enable both social relationships between the elderly people and the creation of an intergenerational learning virtual environment between the older workers, the younger workers and the retired workers*¹¹.

¹¹ See more on the aware Project at: http://www.aal-europe.eu/projects/aware
Support work activities.

Working instruments and workstations should be interactive. Technological and software interfaces should be designed to facilitate the ability of elderly people and non-self-sufficient people to use computers. For example, computers should interact with workers using their own language and explaining to them how they could easily carry out work tasks.

Prevent and reduce the prevalence of work-related diseases.

Smart wireless sensor networks, which monitor instruments, workers, and surrounding environments, and advanced processing algorithms of data events, allow to monitor the state of workers’ health, to maintain the best environmental conditions, to recognize potentially dangerous events and to promptly alert the people responsible for workers’ welfare.

Moreover, ICT solutions may help retired senior professionals to participate in society in the post-retirement years by developing networks of online knowledge sharing and communities.

4. Market Analysis for AAL products, systems and services

In the previous paragraphs the enabling technologies for AAL solutions were described and some significant examples of applications of these systems/services to the needs of an ageing society were given. Here we will focus on the market opportunities in this area, aiming to illustrate the current situation and analyze if and how the implementation of RRI concepts in the ICT industry could impact on the market perspectives for AAL.

The AAL market has been analyzed in detail in the Report *ICT & Ageing – European Study on Users, Markets and Technologies*, prepared by Empiric and WRC on behalf of the European Commission [Ref. 10]. This Report is considered as a benchmarking text. An updating of the 2010 situation has been presented in the *Summary Market Review for AAL* prepared by AALIANCE2 in 2013 [Ref. 11]. The next paragraphs mostly summarize the findings and underline the key issues identified in these documents.

The landscape of service provision for support of independent living for older people is typically structured in the following domains: social care, health care, and housing [10]. A cross-cutting element, enabled by ICT developments, concerns provision of services and supports on a mobile basis (indicated as “mobility”). These core service domains were mapped by Kubitschke and Cullen [9] in the three core technology domains used for the benchmarking and market analysis presented in their report: Telehealth, Telecare, and Smart Homes (Fig. 17).

- **Telehealth** focuses on gathering biometric information through specialized peripherals. Clinical sensors are customised based on the health condition being monitored. In the future, sensors are likely to be ingested or worn on the skin for extended periods to supply clinical monitoring of specific conditions like the amount of chemicals in the bloodstream. Non-clinical sensors are increasingly common in use with smart phone applications, but with the end user as the target user of the gathered data instead of a medical practitioner.
• **Smart Homes** systems are more traditional in sensing the physical state of an enclosed area, i.e. in monitoring for movement (motion detection), gasses (CO, Smoke), entrance/exit (door entry), heat and water. In addition to monitoring, the solutions also include remote actuators to preform simple tasks like opening curtains and turning on/off electrical equipment.

• **Telecare** in its simplest form is a home gateway for automated and actuated alerts: if an alert is raised a response happens. The life critical nature of social alarms also effects the reliability requirements for sensors. The performance requirements typically exceed those found in smart homes.

### 4.1. Market Maturity

Of the three AAL sectors described above, **Telecare is nowadays the most established market** with products focused on the sensing of events (mainly social alarms). More advanced Telecare (2nd generation Telecare) is starting to be mainstreamed in some European countries (e.g. United Kingdom, Spain, Finland, the Netherlands, Germany), often relying on call/monitoring center-based service models. For more advanced Telecare, involving extensive activity monitoring, data gathering and lifestyle analysis, implementation has mostly been done in pilots/trials, often government funded or subsidized.

**Telehealth market is smaller than Telecare**, but with potential for fast growth due to the strong connection to the broad health services market. Overall, the United States and Japan appear to
show most development. To date in Europe the United Kingdom has made the most progress in scale deployment of telehealth followed by Spain and Denmark.

Smart Homes and home automation is also a developing market, but explosive market growth has not yet happened. There are a lot of RTD projects, trials and demonstrators in these fields but no well advanced mainstreaming in most EU countries to date. Some applications are starting to be developed in the Netherlands and Finland.

A detailed description of the AAL market situation in different European countries is reported in Ref. [10] and up-dated in Ref. [11].

4.2. Barriers to Market development.

Eight main barriers to market development are identified in Ref. 10. These are:

1. **Uncertainty about the case for ICT-based solutions.**
   Some concern is raised about the effective contribution of technology-based solutions to meeting the essentially human needs of older people and fitting with the whole range of human services that until now have traditionally complied with these needs.

2. **Value case.**
   There is a large body of evaluation results showing positive outcomes from telecare and other ICT-based technologies to support older people, but much of the indication comes from limited trials and pilots, and there is a lack of evidence for longer term contribution and value of more advanced systems under real life conditions. For this reason, between 2010 and 2013 several research projects have tried to prove the value case for ICT. One of particular note is the Whole Systems Demonstrator project\(^{12}\) conducted in the United Kingdom by following a population of over six thousand people for two years. Their conclusions are not considered definitive, however it is broadly agreed that use of ICT for the elderly may result in savings, quality of care can increase and this can lead to better quality of life for users.

3. **Business case.**
   An important limiting factor is the lack of a demonstrated business or economic case, partially due to the ways that social care services are conceived, provided and funded/reimbursed across different countries. Nevertheless, a strong potential business or economic case is emerging for both telecare and home telehealth, at least at the level of the overall 'system' or public purse, in spite of some lack of awareness amongst social and healthcare policy makers.

4. **Ethical issues.**
   Different levels of ethical issues have to be considered in order to support wider acceptance and appropriate deployment of ICTs for independent living and home care of elderly population. One level concerns macro-ethical issues, such as ensuring that search for cost savings does not reduce drastically the necessary and desirable human services and does not affect the equality across the population in regard to access to essential services. On the

\(^{12}\) [http://www.telecare.org.uk/industry/whole-system-demonstrator-project](http://www.telecare.org.uk/industry/whole-system-demonstrator-project)
other hand, micro-ethical issues are linked to aspects of privacy, as in relation to surveillance in the home, lifestyle monitoring and so on.

5. **Un-conducive reimbursement and incentives systems.**
Getting innovations such as ICT-based products and services onto the lists of publicly funded care/health services & products is difficult and slow in many countries.

6. **Fragmentation of systems and services.**
The still existing lack of integration between the different AAL systems builds important barriers to implementation and to achievement of benefits. In particular, the lack of structures and processes to support continuity of care and integration of care between the different players and levels (hospital and primary care, general practitioners and specialists, and so on) is a limiting factor for home telehealth.

7. **Un-receptive or underdeveloped regulatory regimes.**
Present medico-legal and other regulatory regimes are not well developed from the point of view of the specific characteristics of telecare and home telehealth services and may create barriers to the exploitation of their potential. In particular, as regards telehealth, concerns about liability and risk have been identified as a significant barrier to the mainstreaming of homecare technologies and services.

8. **Resistance to change and lack of capacity to innovate.**
The last barrier is created by the professional resistance to change and by the lack of willingness/capacity in most organizations to change and innovate.

The first three points can be summarized by affirming that the many people are skeptical that ICT can or should play a leading role in caring for the elderly. Acceptance of AAL products/systems could be effectively enhanced by involvement of all societal actors in the R&I (Research and Innovation) process. Ethical issues addressed in Point 4 could also be positively impacted by inclusion of RRI principles in the ICT for an ageing society. The following three barriers (un-conducive reimbursement, fragmentation of systems and services and unreceptive regulation) have a direct impact to how the market will develop and broadly deal with organizations that will support and pay for goods and services.

4.3. Stakeholders

To understand the market further it is necessary to identify the groups participating in the commissioning, supplying, delivering and receiving the services.

The categories of stakeholders in the area of ICT for ageing, as identified in the framework of the BRAID Project\(^{13}\), are reported in the following Table I.

The needs and interests of the different stakeholders are analyzed in detail in the documents produced by the Project BRAID\(^{13}\). Here we concentrate on the tertiary stakeholders, i. e. companies and service providers that design, develop and sell AAL solutions.

\(^{13}\) BRAID Project: Bridging Research in ageing and ICT development (http://www.braidproject.eu/)

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Table I. Categories of Stakeholders in the area of ICT solutions for an ageing society.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Type of Stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Stakeholders</td>
<td>Private users:</td>
</tr>
<tr>
<td></td>
<td>• Senior and impaired citizens</td>
</tr>
<tr>
<td></td>
<td>• Private caregivers; family members and relatives</td>
</tr>
<tr>
<td>Secondary Stakeholders</td>
<td>Professional users:</td>
</tr>
<tr>
<td></td>
<td>• Medical professionals e. g. operating a tele-medicine center</td>
</tr>
<tr>
<td></td>
<td>• Professional care providers; care homes</td>
</tr>
<tr>
<td></td>
<td>• Housing Associations</td>
</tr>
<tr>
<td></td>
<td>• Mobility Providers e. g. Public Transport</td>
</tr>
<tr>
<td></td>
<td>Members of this group have a B2C\textsuperscript{14}-relation to the Primary Stakeholders i. e. they “sell” ICT for ageing solutions to clients and have a B2B\textsuperscript{15}-relation to tertiary stakeholders, i. e. they “buy” ICT for ageing solutions from suppliers.</td>
</tr>
<tr>
<td>Tertiary Stakeholders</td>
<td>Suppliers:</td>
</tr>
<tr>
<td></td>
<td>• Research Organizations : public and private</td>
</tr>
<tr>
<td></td>
<td>• Enterprises</td>
</tr>
<tr>
<td></td>
<td>o Large enterprises with a business in telemedicine and/or telecare</td>
</tr>
<tr>
<td></td>
<td>o Providers of ICT infrastructures: networks and databases</td>
</tr>
<tr>
<td></td>
<td>o Small and Medium size enterprises : hardware, software and/or services provisions</td>
</tr>
<tr>
<td>Quaternary Stakeholders</td>
<td>Supporters:</td>
</tr>
<tr>
<td></td>
<td>• Policy Makers</td>
</tr>
<tr>
<td></td>
<td>• Social and Private Insurance companies</td>
</tr>
<tr>
<td></td>
<td>• Employers</td>
</tr>
<tr>
<td></td>
<td>• Public Administration</td>
</tr>
<tr>
<td></td>
<td>• Standardization Organizations</td>
</tr>
<tr>
<td></td>
<td>• Civil Society Organizations</td>
</tr>
<tr>
<td></td>
<td>• Media</td>
</tr>
</tbody>
</table>

There are many organizations and companies focused on providing solutions for addressing the user’s needs with supportive technologies. The market today is usually segregated into different specialized segments. An outline of AAL systems/services is presented in Table II.

\textsuperscript{14} B2C (Business-to-Consumer) refers to best practices used to promote products and services among consumers.

\textsuperscript{15} B2B (Business-to-Business ) refers to commerce transactions between businesses.
Table II - Synopsis of AAL technical solutions/systems for different application domains.

<table>
<thead>
<tr>
<th>AAL Technology Area</th>
<th>AAL Market Sector(s)</th>
<th>Service Area</th>
<th>Service Technical Components</th>
<th>Service examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensing</td>
<td>Telecare-Smart homes</td>
<td>House monitoring</td>
<td>Sensors to monitor the state of the house</td>
<td>Smoke, intrusion, flood, gas leak</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sensors to monitor electrical usage, temperature/humidity control</td>
<td>Electrical meters, automated climate control</td>
</tr>
<tr>
<td>Acting</td>
<td>Telecare-Smart homes</td>
<td>House automation</td>
<td>Actuators to enable/manage actions</td>
<td>Lighting control</td>
</tr>
<tr>
<td>Acting</td>
<td>Telecare-Smart Homes</td>
<td>House access control</td>
<td>Electronic/digital locks</td>
<td>Keyless entry systems</td>
</tr>
<tr>
<td>Acting</td>
<td>Telecare</td>
<td>Resident physical assistance</td>
<td>Devices for providing assistance for physical tasks</td>
<td>Stair lifts</td>
</tr>
<tr>
<td>Sensing/Reasoning/Acting/Communicating</td>
<td>Telecare</td>
<td>Resident monitoring/emergency alarms</td>
<td>Sensors working with triggers to raise alarms, care phones</td>
<td>Call for assistance</td>
</tr>
<tr>
<td>Reasoning/Acting</td>
<td>Telecare</td>
<td>Resident memory assistance</td>
<td>Assistive Technologies for mental exercise</td>
<td>Medicine reminder Pill dispenser</td>
</tr>
<tr>
<td>Sensing/Communicating</td>
<td>Telehealth</td>
<td>Biometric tracking/monitoring</td>
<td>Systems to measure, store, communicate physiological parameters</td>
<td>Smart phones for telehealth</td>
</tr>
<tr>
<td>Sensing/Reasoning/Acting/Communicating</td>
<td>Telehealth</td>
<td>Telehealth monitoring</td>
<td>Biometric monitors incorporated into official health systems</td>
<td>Remote health care systems</td>
</tr>
<tr>
<td>Sensing/Reasoning/Acting/Communicating</td>
<td>Telehealth</td>
<td>Cronic disease management</td>
<td>Multi-sensors/ algorithms/mechatronic systems to identify and manage the correct therapies</td>
<td>Robot-mediated therapies</td>
</tr>
</tbody>
</table>

Products and technologies developed by the companies operating in this area range from simple, home monitoring equipment like smoke detectors and intruder alerts through to home automation. However, very few solutions are commercially available, mostly advanced telecare that work with limited home automation, like controlled lighting.

There are some “activities of daily living” products on the market that sense what actions are happening (or not happening) to give family and care-givers an idea of the activities of the
residence, but few large commercial services. In the Telehealth and Telecare systems, the acquisition of vital signals and health parameters is carried out by point-of-cares, i.e. devices measuring the biomedical signals related to user pathology and connected to phone line or internet.

Nowadays, AAL and ICT researchers are developing wireless wearable sensors and wireless biosensors that will work without the user activation and automatically will acquire data, elaborate them on-board and send information to caregivers, and clinical and socio-medical experts. All the elaboration and processing steps between signal acquisition and transmission to healthcare professionals and clinical experts represent the core business of Telehealth services.

Some examples of companies developing AAL components/systems/services are:

- Robert Bosch Healthcare GmbH (Germany)
- Evaware Ltd (United Kingdom)
- Philips Healthcare (Koninklijke Philips Electronics NV, Netherlands)
- Siemens Healthcare (Siemens AG, Germany)
- Tunstall Ltd (United Kingdom)
- Intel-GE Care Innovations LLC (Ireland)
- Telecom (Italy)
- Telefonica I & D (Spain)
- Swisscom Participations Ltd (Switzerland)
- ST Microelectronics (Italy)
- BodyTel Europe GmbH (Germany)
- Atos Origin (Spain)
- ALCATEL-LUCENT Deutschland AG (Germany)
- Microsoft UK (United Kingdom)
- Ericsson Telecommunication (The Netherlands)
- INDESIT Company SpA (Italy)
- Tiscali Italia S.p.A (Italy)
- megatel GmbH (Germany)
- TP Vision (Belgium)
- Continua Health Alliance
  (200 members, including Panasonic, Intel, IBM, Samsung Electronics, Sharp, Qualcomm Inc., Fujitsu Ltd., Medtronic, Texas Instr.)

Among the established companies few offer products that support all three AAL value domains, i.e. Telecare, Telehealth and Smart homes. Most focus on one domain and possibly expand into a second. For example, a Telecare provider will offer lighting control solutions, or a Smart home provider may offer Telehealth monitoring.

Throughout Europe there are also many start-ups typically funded through partnership with governments, still working to find a market.

A significant number of established companies, SMEs and start-ups active in the development of AAL systems and services participate in the Projects launched by the AAL Platform and their contribution can be appraised in the AAL Catalogue of Projects, 2013 [Ref. 9].
4.4. Market facilitators

The European Commission adopted an *Action Plan on Information and Communication Technologies for Ageing* in the framework of its i2010 Initiative to raise awareness, overcome technical and regulatory barriers, accelerate take-up and boost research and innovation [Ref. 12].

Over the years the Action plan has been successful in stimulating significant technology development, but the markets are still developing at a pace slower than anticipated.

AAL markets need to find their place in the current social and health systems, and especially need to overcome the existing boundaries between social and healthcare, between health professionals and the increasing eHealth services, etc. End users will use the AAL technologies if these technologies answer to their needs and expectations. To achieve this complex objective, several approaches involving the different stakeholders have been identified by ICT & Ageing [Ref. 9] and by AALIANCE2 [Ref. 10]:

1. **Comprehensive promotional programmes** (*government pump-priming funding, public procurement framework agreement for telecare and telehealth products and services, programme of information and awareness-raising...*);

2. **Conducive reimbursement approaches**;

3. **Market and welfare goals combined in innovation policy**;

4. **Regulatory and policy changes to make a more favorable environment** (*through integrated care model, reimbursements of telehealth providers, etc..*);

5. **Interoperability and flexibility as key components in AAL solutions**;

6. **Reliable, flexible and easy to use AAL solutions**;

7. **Fostering market deployment by active involvement of end users**;

8. **Market deployment promotion thanks to a partnership with other stakeholders** (*health professionals, insurers, etc.*);

It is conceivable that the development of AAL market will depend on public policies in the health sector. Nonetheless, it is evident that this market will grow if the end user acceptance of AAL technologies will increase. In fact nowadays end users are not convinced that AAL solutions will effectively improve their quality of life and wellbeing. In order to meet their needs and expectations, the AAL systems/products should be affordable, accessible, reliable and easy to use.
The implementation of RRI concepts in the industry of ICT for an ageing society could impact positively on these aspects. Involvement of the general public in the research and innovation process would bring to an improved matching of ICT products with societal needs, to higher acceptability and increased quality of these products. More in general, an enhanced consideration of societal needs and ethical aspects from the industry could translate into economic benefits.
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