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EXECUTIVE SUMMARY

The primary objective of this report is to present the acquired synthesis of the existing knowledge in digital innovation and implementation of Smart Healthy Age-Friendly Environments (SHAFE) solutions, a critical assessment of practices, and recommendations for the future, in line with the objectives defined for the Working Group 3 of NET4Age-Friendly:

1. Map the state-of-the-art on digital solutions and large-scale sustainable implementation examples enabling SHAFE, through the collation and analysis of existing initiatives, practices implemented and related projects.
2. Collect and analyse former and ongoing research/practices on digital solutions and large-scale implementation and publish such collection in the form of a searchable knowledge base on the Action website (www.net4age.eu).
3. Synthesize and improve the state-of-the-art and good practices through a detailed analysis and the development of recommendations for the future.

The objectives were achieved departing from a comprehensive desk research to address the background and challenges, define scope and purpose, identify target stakeholders, analyse the existing knowledge base, and augment it with new data, thereby contributing significantly to the further development of the framework's Module on digital innovations and implementation.

Based on these findings, the report aims to offer a nuanced understanding of the current digital landscape and tailored approaches that align with the evolving dynamics of technological advancements in the SHAFE areas. Through these insights, it delivers a comprehensive and forward-looking resource in the sphere of digital innovations and implementation towards the promotion of more inclusive communities.

1. INTRODUCTION

1.1 Background and Challenges

The concept of SHAFE (Smart Healthy Age-Friendly Environments) was launched in 2018 within the work of a Thematic Network, approved by the European Commission to build and deliver a Joint Statement in 2018. After this, SHAFE evolved by taking its more than 170 partner organizations to a European Stakeholders Network, which has now evolved to a Foundation, established in the Netherlands, focused on cooperation and implementation. SHAFE is now integrated in several ongoing initiatives, as an objective and methodology of work [1].

SHAFE seeks to promote the development of healthy and welcoming environments for individuals of all ages by harnessing cutting-edge technologies. To be more specific, SHAFE aims to underscore the importance of people and spaces in crafting digital solutions that contribute towards improved quality of life, but still remain accessible to all. The primary objective is to recognize the individual as a central component in the entire digitization process.

This methodology aligns with the United Nations' Sustainable Development Goals, emphasising that creating sustainable environments for all age groups is fundamental to securing a better future for the entire population and addressing the multifaceted challenges posed by an ageing society [2]. The interconnected challenges faced by various sectors, including ICT, construction, urban planning, health, and social care, as well as those encountered by citizens and their communities, highlight the need for a unified response. Addressing these challenges will raise awareness and gather support for producing and implementing smart, healthy and inclusive environments that benefit present and future generations. These environments should facilitate learning, growth, work, social interaction and a healthy lifestyle, leverage digital innovations, accessibility solutions and adaptable support models within the European context [2].

Together with the **green and digital transitions, demographic change** is the third transformation shaping the future of Europe and world. A good understanding of how demographic change and the local, regional and national realities interact is the key to tailor national policies to the changing conditions on the ground. Demographic knowledge is cross-cutting: demographic drivers and implications of territorial disparities across regions provide unique and detailed insights to tackle societal challenges and to understand political attitudes even better. In contemporary society, we are witnessing a variety of changes - demographic, socio-economic, cultural, climate, and digital, among others. These transformations profoundly impact individuals and humanity, from local to global levels. Demographic trends are one of the most important factors of societal development as they lead to transformation of social, political, economic, cultural and other processes [3].

1.2 Demographic background

The low fertility rate in Europe and in many other parts of the world and the progress achieved in health, social and economic measures that extend the life, have led **to deep and long-term changes of the age structure**. For this reason, a major part of the world, and Europe as a whole, is faced with **demographic ageing** and depopulation. The number of older people is increasing faster than the number of people of any other age category and therefore, their share in the total population is also increasing. According to United Nations estimates, the number of people older than 65 years of age will, by mid-21st century, for the first time in human history, exceed the number of children younger than 5, even children younger than 14, and every fourth inhabitant of the planet will be over the age of 65. At the same time, due to the increase in life expectancy, the part of the population over 80 and 85 years old is at the highest increase in many countries in the last few years, so the world is faced with a fast demographic ageing of the old population [4].

The central focus of the United Nations (UN) Decade of Healthy Ageing 2021-2030 lies in the meaningful involvement of older individuals, acknowledging and honouring their roles, rights, and entitlements as both catalysts for positive change and recipients of services [5].

This global initiative underscores the inherent rights of older people, emphasizing their entitlement to the highest achievable standard of health. Envisaging a world where individuals experience long and healthy lives, the Decade aligns itself with the Sustainable Development Goals (SDGs) and operates as a collaborative effort on a global scale. The UN Decade of Healthy Ageing specifically targets individuals in the latter stages of their lives, aiming to enhance the wellbeing of older people, their families, and the communities they inhabit. Recognizing the potential for each older person to drive transformative change, the Decade outlines a vision that necessitates action across four key areas, spanning various levels and sectors. These actions are geared towards promoting health, preventing diseases, preserving intrinsic capacity, and optimizing functional ability in older individuals [5].

The Decade therefore calls on stakeholders in many sectors to work together to address the four areas for action:

- changing how we think, feel and act towards age and ageing;
- ensuring that communities foster the abilities of older people;
- delivering person-centred integrated care and primary health services that are responsive to older people;
- providing access to long-term care for older people who need it [5].

These areas are interconnected and mutually reinforcing. The work of stakeholders around the world to achieve these action areas will foster healthy ageing and improve the wellbeing of older people. Strong collaboration for transformative change in these areas will benefit from four Decade enablers [5]:

- listening to diverse voices and enabling meaningful engagement of older people, family members, caregivers, young people and communities;
- nurturing leadership and building capacity for integrated action across sectors;
- connecting stakeholders around the world to share and learn from the experience of others;
- strengthening data, research and innovation to accelerate implementation.

The anticipated demographic trends in the European Union (EU) reveal a dynamic shift in population dynamics. The total EU population is expected to rise from 449 million people in 2022 to a peak of 453 million people in 2026. After that, it would fall to 432 million in 2070, a decline by 4% compared to 2022.

The population of older people (aged 65 years or more) in the EU-27 will increase significantly, rising from 90.5 million at the start of 2019 to reach 129.8 million by 2050. During this period, the number of people in the EU-27 aged 75-84 years is projected to expand by 56.1 %, while the number aged 65-74 years is projected to increase by 16.6 %. By contrast, the latest projections suggest that there will be 13.5 % fewer people aged less than 55 years living in the EU-27 by 2050.

As shown in Figure 1, for the EU the size of older age groups would grow, while younger age brackets would shrink. The few countries where the working-age population (people aged 20 to 64) is projected to increase would see an even greater increase in the population aged 65 or more [6] [7].

Perhaps the most remarkable aspect of the projected changes to the EU's population structure concerns the progressive ageing of the older population itself: the relative importance of the very old (people aged 85 years or more) is growing at a faster pace than any other age group. Between 2019 and 2050, the number of very old people in the EU-27 is projected to more than double, up 113.9 % [6].

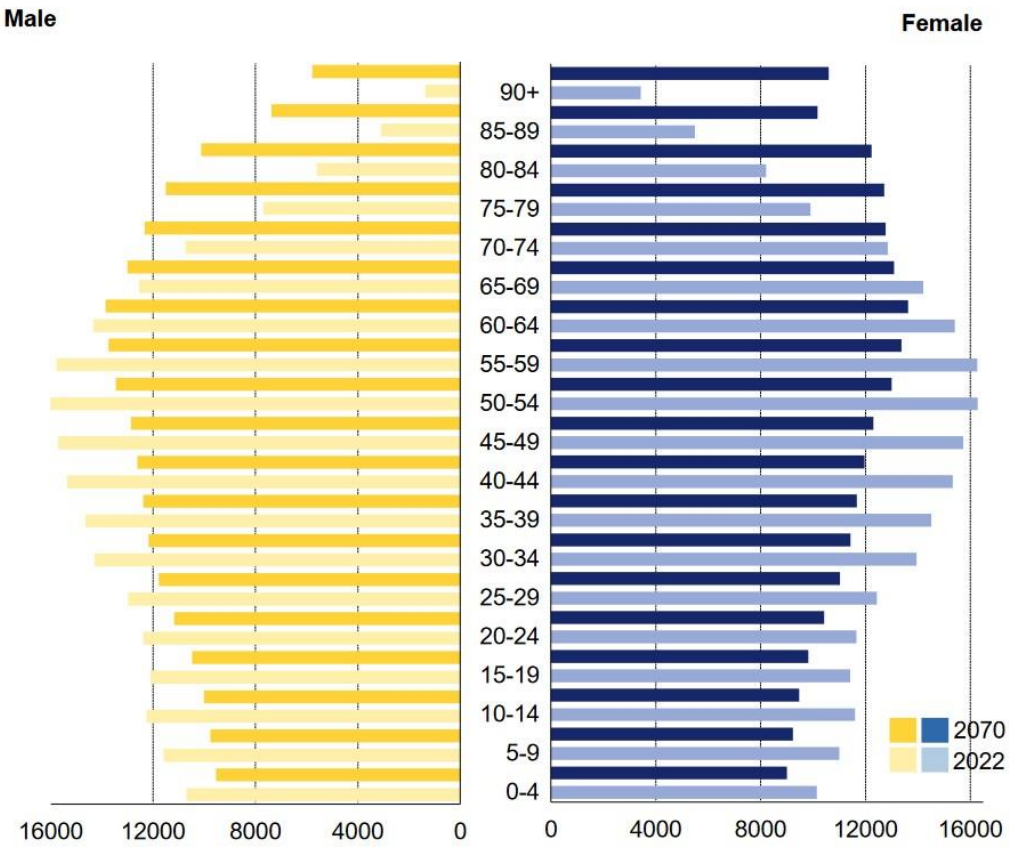


Figure 1 - EU- Population by age group and sex, 2022 and 2070 [7]

The old-age dependency ratio illustrates the relative shift between potential retirees and potential workers, and thus how an ageing population changes the beneficiary-contributor balance. This ratio will rise sharply in all Member States over the next decades as a result of the projected dynamics in both groups. From around 29% in 2010, it rose to 36% in 2022 and would rise further to 59% in 2070, with the majority of the increase expected by 2045.

In other words, the EU will have nearly thirty people aged 20 to 64 for every ten people over the age of 65 in 2022, but only twenty people by 2045. More than two-thirds of EU Member States are expected to have an old-age dependency ratio of more than 50.0% by 2050; that is, they will have fewer than two people of working age for every person aged 65 or older (Figure 2). The old-age dependency ratio is projected to reach at least 60.0% in seven Member States, with Italy (66.5%), Greece (68.1%), and Portugal (68.8%) having the highest ratios. At the other end of the spectrum, Cyprus's old-age dependency ratio is expected to remain below 40.0% in 2050 [7] [6].

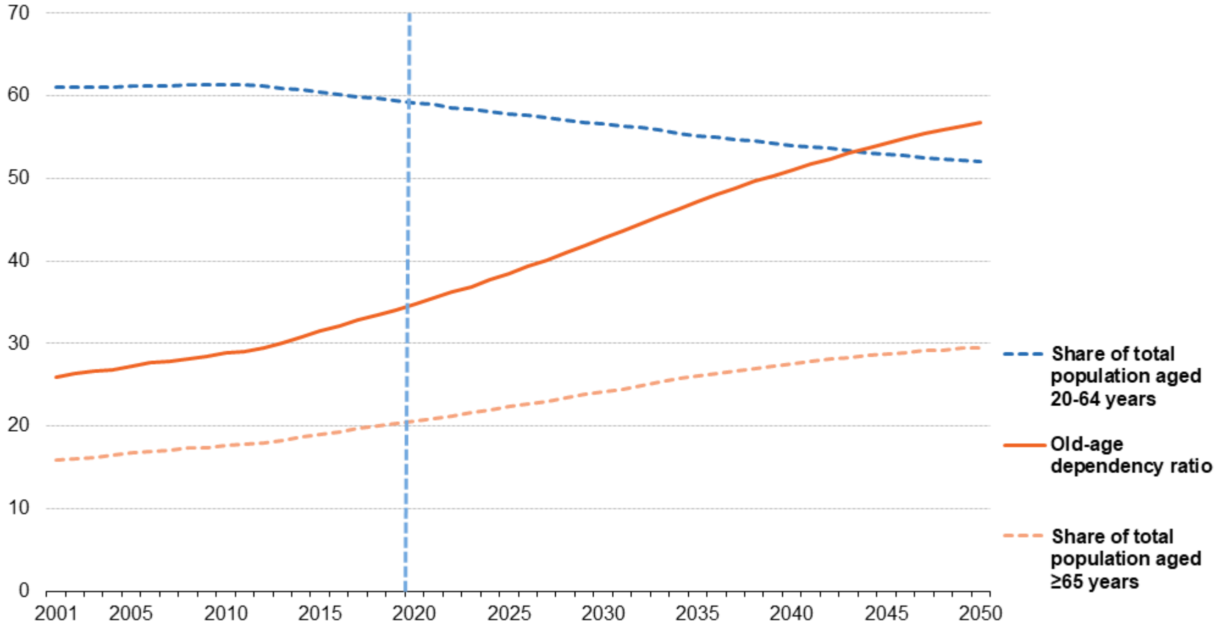


Figure 2 - Population structure indicators, EU-27, 2001-2050 [6]

Acknowledging that the 21st century is characterized by a significant rise in life expectancy and a growing ageing population, this societal shift has become a central focus in numerous public policies. To effectively navigate these inevitable shifts, it is required to explore innovative forms of support.

1.3 Socio-economic background and challenges

The world has largely shifted to digital and its population is ageing. Older persons have always been an asset to their families, communities and societies. Nevertheless, they have been perceived as a vulnerable group dependent on young generations. The digital world can no doubt enable older persons to participate and contribute to society turning this misconceptionof vulnerable into valuable. It is therefore important to prioritise ageing as a global key policy issue. All policy-makers and stakeholders including governments, academia, companies, industries, and entrepreneurs need to seize the possibilities for development that ageing brings. Improvements in health conditions allow older adults to have a more productive longevity; moreover, a number of social, economic and business opportunities arise from this demographic revolution [8].

As the global population continues to age, there are several socio-economic implications associated with this demographic shift. Some key aspects include:

1. **Increased Healthcare Costs:** Ageing is linked with a rise in chronic health conditions and increased demand for healthcare services. This places a strain on healthcare systems, leading to higher costs for both individuals and governments.
2. **Pension and Social Security Challenges:** As more people retire and live longer, pension and social security systems face challenges in maintaining financial sustainability. Adequate retirement income becomes a concern for many older people.
3. **Workforce Impact:** An ageing population can affect the labour market, leading to potential labour shortages and changes in workforce dynamics. There may be a need for new policies to encourage older individuals to stay in or re-enter the workforce.
4. **Housing and Urban Planning:** The ageing population often requires accessible housing and infrastructure. Urban planning needs to consider the needs of older citizens, including accessible public spaces and transportation [6].

Ongoing demographic trends will have significant consequences for the EU public finances. Based on current policies, it is estimated that 'exclusively' age-related (pensions, health, and long-term care) public expenditure will increase by 4.1% points of GDP between 2010 and 2060, from 25% to 29%. The expenditure on pensions alone is expected to increase from 11.3% to nearly 13% of GDP by 2060. However, there are significant differences between countries, depending largely on the progress made by each country in the reform of the pension system, which confirms the need for policy action to meet the challenges of an ageing population [2].

Social isolation and loneliness among older adults are priority public health problems, as well as national and international policy issues, due to the negative impact on their mental and physical health and longevity [9] [10] [11].

More than half of the world's population currently resides in urban areas, a figure projected to increase to 80% by the year 2050. Cities and metropolitan regions serve as hubs for economic activities, knowledge creation, innovation, and the development of new technologies. They wield a profound influence on the quality of life for residents and workers, while also playing a pivotal role in addressing global challenges. The concept of a smart city involves optimising traditional networks and services through the integration of digital and telecommunication technologies, all aimed at enhancing the wellbeing of inhabitants and fostering business growth. Beyond merely leveraging information and communication technologies (ICT) for improved resource utilisation and reduced emissions, a smart city envisions more efficient urban transport systems, upgraded water supply and waste management infrastructures, and innovative approaches to lighting and heating buildings. Furthermore, it encompasses a dynamic and responsive city administration, the establishment of safer public spaces, and a commitment to meeting the evolving needs of an ageing population. In essence, a smart city represents a comprehensive and forward-thinking approach to urban development that utilizes technology to create more sustainable, efficient, and liveable urban environments [1].

In order to implement the European Green Deal effectively, it is imperative to reconsider policies related to the provision of clean energy across various sectors of the economy. This includes industry, production and consumption, large-scale infrastructure, transport, food and agriculture, construction, taxation, and social benefits.

Achieving these goals requires placing greater emphasis on the preservation and restoration of natural ecosystems, sustainable resource utilization, and enhancements to human health. It is within this sphere of transformative change that the most significant and potentially advantageous shifts can occur for the European Union's economy, society, and natural environment [1].

Challenges exist concerning the accessibility of digital interventions and the utilization of remotely delivered solutions aimed at mitigating social isolation and loneliness. The unequal availability of these digital interventions has become a pressing issue, particularly for older adults, especially in the context of COVID-19 restrictions. A significant number of older individuals face barriers in adopting digital tools due to a lack of skills and confidence in accessing online services. Affordability and accessibility of technology, as well as challenges related to broadband or Wi-Fi availability, data poverty (which refers to a lack of access to wireless internet connection), and geographical disparities (such as rural-urban distinctions and differences between high-income and low- and middle-income countries) contribute to the widening divide [9].

Having in mind that most of the challenges are related to health, WHO launched ageing data portal that stores and displays country, regional and global data on important ageing health indicators, available as Ageing country profile (Figure 3).

Italy

Decade of healthy ageing

Top 10 causes of death in older people and years lived with disability

Rank	Causes of death	Causes of years of healthy life lost due to disability
1	Cardiovascular diseases	Musculoskeletal diseases
2	Malignant neoplasms	Sense organ diseases
3	Ischaemic heart disease	Neurological conditions
4	Stroke	Mental and substance use disorders
5	Neurological conditions	Diabetes mellitus
6	Respiratory diseases	Cardiovascular diseases
7	Ischaemic stroke	Unintentional injuries
8	Alzheimer disease and other dementias	Other hearing loss
9	Chronic obstructive pulmonary disease	Alzheimer disease and other dementias
10	Trachea, bronchus, lung cancers	Back and neck pain

Data source: WHO - Global Health Estimates (GHE) (2019)

Integrated Care for Older People

Age Groups	Prevalence and incidence of common health conditions			
	Hearing loss*	Blindness and vision impairment*	Low back pain*	Falls**
60-64	31%	6%	19%	2777
65-69	41%	8%	20%	3279
70-74	51%	11%	21%	4699
75-79	59%	17%	22%	7738
80-84	66%	25%	23%	13195
85-89	70%	34%	22%	19459
90-94	75%	43%	21%	26948
95+	80%	51%	19%	35515

Prevalence** ** Incidence**

Data source: IHME (2019)

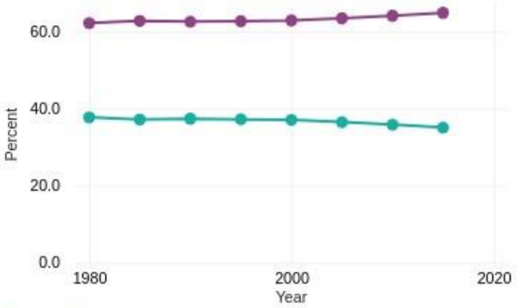
Age-friendly cities and communities

	Year	%
Percentage of older people living in age-friendly cities and communities	2023	3.0%
Percentage of older people receiving pension	2018	94.4%
Percentage of older people active in labor market	2022	5.1%
Percentage of older people living in rural areas	2015	35.1%
Percentage of older people living in urban areas	2015	64.9%

More information: Age-friendly World

Data source: ILO, WHO, UN Population Division

Percentage of older people living in rural and urban areas



Data source: UN Population Division

Long-term care for older people

	Year	%
Percentage of older people receiving long-term care at long-time care facilities (aged 65 years or over)		no data
Percentage of older people receiving long-term care at home (aged 65 years or over)	2022	5.6%
Number of formally employed LTC workers per 100 older persons (aged 65 years or over)		no data

Data source: OECD Stats

World Health Organization

Figure 3 - Ageing Profile of Italy, Page 2 of 4 [12]

The contribution of older people to society is mainly determined by their health, which also impacts the extent of the human and social resources required as we age. There is not enough evidence that longevity comes with a better health today in comparison with the previous generation [13]. Devoting public resources to improving the health of older populations, and healthy lifestyle in general is justified and needed for multiple reasons:

- the human right that older people have to the highest attainable standard of health [14],
- fostering sustainable society development in evolving demographic transition [15],
- the economic need to adapt to shifts in the population age structure to minimize the expenditures associated with ageing society and maximize the contributions that older people make [16].

It is in this context that the United Nations declared 2021-2030 as the Decade of Healthy Ageing, urging governments, civil society, international agencies, professionals, academia, the media and the private sector to concentrate their collaborative efforts to improve the lives of older people, their families and the communities in which they live [8]. Healthy ageing is heavily influenced by environments such as the home, the community and the broader society, and by a range of factors within these environments. These factors include the built environment, people and their relationships, attitudes and values, health and social policies, the systems that support them, and the services that they implement. Being able to live in environments that sustain and maintain one's intrinsic capacity and functional ability is key to healthy ageing [15].

Concerns about the use of digital technology also extend to issues of privacy infringement, legal ramifications, ethical considerations, and clinical data governance, particularly in terms of data sharing and information access. Ethical apprehensions regarding interventions to address social isolation and loneliness encompass factors like accessibility, acceptability, cost, feasibility, autonomy, and informed consent. The intersection of privacy concerns with accessibility issues is notable, especially in cases of cognitive impairment or the involvement of family members or caregivers. Challenges arise with the adequacy of informed consent provided at the start of research, as it may not encompass future data use, leading to ongoing consent and withdrawal issues [9] [11].

Public and private sectors, including all branches of government, entrepreneurs and small businesses, academia and other organizations have engaged in digital transformation. This implies serious rethinking to transform processes and communication channels and adapt to new market requirements. The use of ICTs opens new and exciting opportunities for ageing adults. They can become the best enablers of healthy-ageing environments. It is certain that the role of digital innovation becomes increasingly pivotal in addressing the unique needs and challenges faced by older individuals. While digital solutions have the potential to enhance the quality of life for older people, a range of obstacles exists that hinder their seamless integration into the lives of older adults.

This **intersection of ageing and digital innovation presents a landscape marked by both opportunities and challenges**. ICTs, if built with the digital accessibility requirements and universal design in mind can make a fundamental difference in creating accessible, inclusive and age friendly digital environments and communities [8].

1.4 Challenges associated to wellbeing

In the dynamic interplay between the advancing age demographics and the evolving digital landscape, the potential for enhancing the wellbeing of people at all ages stands-out. Digital innovation offers improved connectivity, healthcare access, and overall higher quality of life. However, within this promising landscape, many challenges unfold, that are addressed below separately as:

1. Digital literacy barriers

Vulnerable individuals may face challenges in adapting to and using new digital technologies due to a lack of familiarity and digital literacy skills. This can result in feelings of frustration, isolation, and reduced access to essential services and information.

2. Social isolation and loneliness

Digital tools hold the promise of connectivity, yet the paradox of social isolation persists. The challenge lies in ensuring that technology not only connects but also mitigates feelings of loneliness, particularly among those with limited social networks. While digital platforms can connect people, there is a risk that more vulnerable people, especially those less familiar with technology, may feel excluded or lonely in the increasingly digital world. Inability to navigate social media or use communication tools can contribute to social isolation.

3. Health monitoring and privacy concerns

Digital health innovations may raise concerns about privacy and data security. People may worry about the collection and use of their health data, impacting their willingness to adopt technologies that monitor health or support telehealth services.

4. Mental health implications

The digital era brings both opportunities and challenges to mental wellbeing. While cognitive health apps and online resources can support mental fitness, the constant influx of information and the potential for digital overwhelm may pose risks to mental health.

5. Quality of digital interactions

The nature of digital interactions, though convenient, may lack the depth and richness of face-to-face communication. Ensuring that digital tools enhance, rather than replace, meaningful human connections is for the overall wellbeing.

6. Digital dependence and addiction

The increasing integration of technology into daily life raises concerns about dependency and addiction, particularly among people who may find themselves spending excessive time online. Striking a balance between digital engagement and other aspects of life is essential for wellbeing.

7. Information overload and health literacy

The abundance of health information online can lead to information overload, challenging individuals to recognise reliable sources. Improving health literacy and providing curated, accessible health information becomes essential for informed decision-making.

8. Physical health impact

Prolonged use of digital devices and sedentary behaviour associated with technology use can impact the physical health. Balancing screen time with physical activity is crucial for maintaining overall health and wellbeing.

9. Digital discrimination and ageism

Digital platforms and applications may not be designed with the specific needs and preferences of older users in mind. Ageist assumptions about technology use can result in user interfaces that are not intuitive or accessible, impacting the overall user experience. Older individuals may face age-related biases and discrimination in digital spaces, leading to feelings of exclusion. Combating ageism in the digital realm is vital for fostering a sense of belonging and wellbeing among older adults.

10. Technostress

The rapid pace of technological change and the need for continuous adaptation to new digital tools may contribute to technostress. Anxiety, frustration, and feelings of overwhelm can adversely affect mental wellbeing.

11. Limited tailored content

The challenge lies in the lack of personalized and tailored content that addresses the specific needs and interests of different groups. Digital platforms need to offer content that enhances cognitive, emotional, and social wellbeing. Personalization is crucial in ensuring that digital tools align with the diverse wellbeing requirements.

12. Access disparities

Economic disparities can limit access to the latest digital technologies. Those with lower incomes may struggle to afford devices, high-speed internet, or necessary software, exacerbating existing inequalities and hindering access to digital wellbeing resources. For example, while digital health solutions can improve healthcare access, challenges exist in ensuring that these tools are inclusive and accessible to all. Addressing barriers to entry, such as digital literacy and device affordability, is crucial for wellbeing.

13. Economic inclusion

The digital economy may inadvertently exclude people who are not actively participating in online marketplaces. Ensuring economic inclusion through digital platforms is vital for the financial wellbeing.

14. Ethical considerations

The use of emerging technologies, such as artificial intelligence in caregiving or companion robots, raises ethical questions. Striking a balance between technological assistance and maintaining the dignity and autonomy, namely of older individuals, is a complex challenge. Navigating these challenges requires a holistic approach that prioritizes wellbeing in the design and implementation of digital solutions. Collaborative efforts from technology developers, healthcare professionals, policymakers, and community organizations are essential to create a digital landscape that genuinely supports the holistic wellbeing of the ageing population.

In conclusion, addressing the challenges arising from the convergence of demographic challenges and digital innovations requires a holistic and collaborative effort. Tackling issues such as digital literacy gaps, social isolation, health and privacy concerns, and ageism in digital design requires a multifaceted approach. Promoting inclusive design, enhancing digital literacy, safeguarding privacy, and considering ethical implications are crucial steps. By fostering a supportive environment and encouraging ongoing education, we can create a digitally inclusive landscape that enhances the overall societal wellbeing.

2. OBJECTIVES

We are all currently experiencing a growing dependence on ICTs. Governments, enterprises, academia and entrepreneurs are all in the midst of implementing digital transformation processes in order to better serve their citizens and better adapt to new consumer trends where low physical contact prevails.

Nevertheless, not all are taking into consideration the characteristics and needs of vulnerable people, considering their age, gender and skills. The **main scope** of the digital innovations and implementation of the SHAFE approach is focusing on the *integration of digital technologies to enhance the wellbeing and quality of life of people at all ages. The scope encompasses various areas and industries, strategically addressing real-world challenges faced by ageing populations.*

In this report we identified following **key areas:**

1. Healthcare

The Integration of digital health solutions (e-health), telemedicine (m-health), and remote patient monitoring for improved healthcare access and personalized services. The use of health apps has increased as they have proven helpful for monitoring and preventing more serious conditions. It improves the prevention of illness and boosting health and wellbeing at all ages via devices and apps (sensors, monitors, wristwatches, and mobiles) for continual health monitoring and feedback.

2. Social services

Development of digital platforms and tools to foster social connections, reduce social isolation, and provide support services for people in different phases of their life course. The digital transformation process has increased the range of products and services online. A user-friendly customer service can also help those clients who are not familiar with digital platforms. Well-designed mobile application (e-commerce) and websites that take into consideration universal design, as well as the needs of the ageing population, are important to ensure the transition of the group to online services and products.

3. Community engagement

Implementation of digital solutions to enhance community engagement, participation, and collaboration, promoting an active and inclusive ageing community. Communities may also take advantage of the working experience of the retired community. Entrepreneurs as well as young workers with little experience may leverage the opportunity of receiving the advice of retired people. With the use of digital platforms, this type of working relation is possible and available.

4. Urban environments

Use of digital innovations to create age-friendly urban spaces, including smart transport networks, accessible infrastructure, and responsive city administration. A necessity as basic as the purchase of groceries can be done online, thus enhancing the wellbeing of those who cannot use transport and carry bags.

5. Financial inclusion

Integration of digital tools to address financial challenges, promote economic inclusion, and provide access to online resources for financial planning and support. Businesses are changing their traditional models to digital ones and provide good opportunities for people to meet their basic needs. Digital banking (e-banking) for example, was a good example in the last few years when it enabled to manage savings independently without risk of exposure to COVID-19 in bank branches during the pandemic [8].

6. Education and digital literacy

Implementation of educational programs and digital literacy initiatives to empower individuals with the skills needed to navigate digital technologies effectively. E-learning platforms have now made education more affordable and have opened up more options for the population. Academia and learning programmes should provide options that might be of interest to this growing group of society. Online leaning platforms also need to be user-friendly to include or maintain the contributions of older teachers and mentors for the benefit of younger generations [8].

In navigating these challenges and targeted areas, a holistic approach is essential, involving collaborative efforts from main groups of stakeholders:

- policymakers,
- technology developers,
- healthcare professionals,
- community organizations.

The **SHAFE** approach underscores the creation of environments that are not only technologically advanced but also prioritize health, inclusivity, and age-friendliness. This involves:

- Designing and implementing smart technologies that support active and healthy living.
- Ensuring accessibility and usability of digital solutions by people at all ages.
- Promoting social connectivity and active engagement through digital means.
- Addressing challenges related to digital literacy and ensuring that educational components are aligned with the SHAFE principles.

According to the World Health Organisation (WHO), healthy ageing includes meeting basic needs: learning, growing and making decisions; maintaining mobility; building and maintaining relationships and contributing to society. Including technology in the equation of those objectives can be the key to achieving them sooner and in a better way if the relevant considerations are considered in order to create age-friendly environments [8]. Considering all explained above, the **digital innovations and implementation of SHAFE solutions module** aim to achieve the following impactful **outcomes**:

- Improved well-being and quality of life for people at all ages through targeted digital interventions.
- Enhanced accessibility to healthcare, social services, and community resources.
- Fostering a sense of connectivity and reducing social isolation.
- Facilitating active participation in urban life and promoting age-friendly urban environments.
- Empowering individuals through digital literacy initiatives, fostering independence and inclusion.
- Contributing to the creation of a sustainable, smart, and healthy environment for ageing populations.

In summary, the digital innovations and implementation module, guided by the SHAFE approach, strategically addresses challenges in healthcare, social services, community engagement, urban environments, financial inclusion, and education. The intended impact is to create a transformative and inclusive digital landscape that significantly enhances the wellbeing of people of all ages in various aspects of their lives.

ICTs and digital solutions can significantly increase the commercial prospects that arise from the ageing revolution. The best equalizer of development opportunities for all people, including those who may have lost some abilities, is technology. Without a doubt, encouraging older adults to use and have access to ICTs is crucial to fostering a culture of healthy living. ICTs have the potential to be one of the greatest tools for people to age healthily if their needs and characteristics are considered. This is perhaps why the entire economy catering to the needs of older adults, also known as the "silver economy" or longevity economy has expanded significantly in the last few years [8].

From various angles, the ageing population presents a business opportunity. On one hand, it symbolizes a potential long-term customer. However, it also possesses invaluable experience that it could use to help entrepreneurs and younger generations, fostering intergenerational communication. Specifically, "age technology," which refers to any technological goods and services created with and for older people, has enormous potential to support inclusion and development. Businesses, academic institutions and entrepreneurs should investigate this underutilized market since it will continue to expand at an exponential rate, affecting the labour and financial markets in addition to the demand for goods and services [8].

It is important for countries to consider these opportunities, adapt and make adjustments. If societies anticipate and respond flexibly to ageing-related needs and preferences, they will most successfully take advantage of the ageing process, including the design and development of ICTs according to needs and requirements of older persons. To maintain clients, all industries need to think ahead about potential age-related conditions. Digital literacy and inclusion are needed to ensure the potential enabling factor of ICTs. The key is to guarantee an inclusive environment which must take account of age-friendly technological considerations. Everyone in society is adapting to technology, but it is the role of developers and manufacturers to consider that not everyone adapts at the same pace [8].

By understanding and addressing the unique needs of people at all ages, digital innovations can evolve to become more inclusive, user-friendly and supportive. The goal is to transform the challenges posed by the intersection of ageing and digital innovation into opportunities for improved wellbeing and connectivity. ICTs possess significant capacity to diminish social and economic disparities that impact many people. However, they can also intensify existing inequalities and even generate new ones. It is crucial for all parties involved, particularly governments, to ensure that public policies actively support the beneficial impact of emerging technologies [17]. Such tools have the potential to generate opportunities for the integration of people in various scenarios [8] [15].

In this case, digital inclusion is the key to getting more people to take part in the information society's social and economic life. The term "digital inclusion" (Figure 4) means that everyone, no matter their gender, age, or location, can access and use information and communication technologies. To make this happen, digital inclusion needs three basic things: a digital infrastructure, easy access to ICT, and people using technology [8] [18].

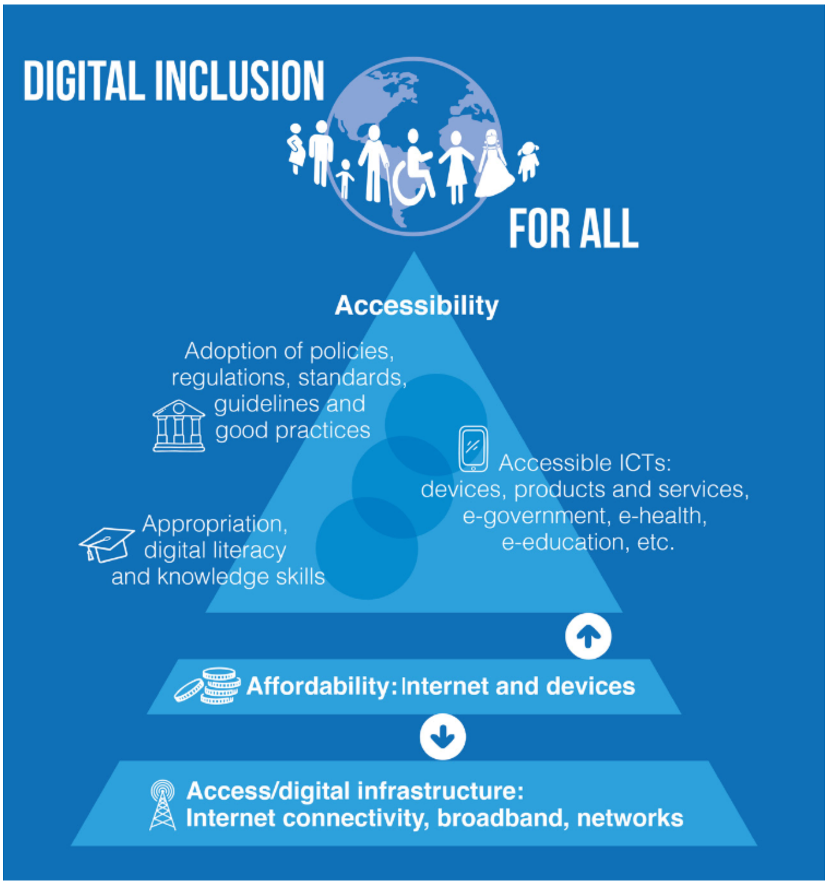


Figure 4 - Digital inclusion explained [8]

Digital solutions are a catalyst for economic and social growth as well as a bridge to the outside world while minimizing the impacts of isolation. Nevertheless, it is essential that content is created according to the needs of people of all ages. Including them in the process of developing products and services will be the key to achieving inclusive technological environments, thereby promoting active and healthy living. Meeting these requirements will also create major investment and production opportunities, so it is very important to targeted adequate and relevant stakeholders, as described in the following chapters.

3. STAKEHOLDERS TO ENGAGE FOR SHAFE

The intersection of technology and the main societal areas needed for active and healthy living has become a focal point of innovation and transformative change. In response to this dynamic convergence, the concept of Smart Healthy Age-Friendly Environments (SHAFE) has emerged, emphasizing the integration of digital innovations to enhance the wellbeing of all people. This paradigm shift calls for a comprehensive exploration of the digital innovation ecosystem, where diverse stakeholders collaboratively contribute to the creation of age-friendly, technologically advanced environments. Identifying the stakeholders within the digital innovation ecosystem relevant to the SHAFE concept encompasses a diverse range of actors, and engaging these stakeholders is essential for the successful implementation and impact of digital innovations in creating Smart Healthy Age-Friendly Environments.

SHAFE began as a Thematic Network, approved by the European Commission, to draw policy makers, organisations and citizens' attention to the need of better alignment between health, social care, built environments and ICT, both in policy and funding. After this, SHAFE evolved to a European Stakeholders Network (**Erro! A origem da referência não foi encontrada.**), which currently has over 170 partner organizations [19]. COST Action NET4Age-Friendly, that works around the concepts of SHAFE, aims to establish an international and interdisciplinary network of researchers and stakeholders from all sectors to foster awareness, and to support the creation and implementation of smart, healthy indoor and outdoor environments for present and future generations, promoting social inclusion, independent living and active and healthy ageing in society [20].

Within this context, the digital innovation ecosystem plays a pivotal role. It encompasses a diverse array of stakeholders, each contributing a unique perspective and expertise to the development, implementation, and utilization of digital solutions aligned with the SHAFE concept. From industry leaders driving technological advancements to policymakers shaping the regulatory landscape, and from researchers uncovering evidence-based practices to promote societal good to all people benefiting directly from these innovations—all stakeholders play a vital part in shaping the future of living in a digitally connected world.

This chapter aims to identify and categorize the stakeholders within the digital innovation ecosystem relevant to SHAFE. From industry leaders and policymakers to technology developers and advocacy groups, this part dissects the roles and contributions of each, emphasizing their significance in creating age-friendly, technologically enriched environments for all people.

The following list is based on analysing existing networks, available relevant documents and pioneers in implementing digital solutions connected to the SHAFE concept.

- **Industry leaders**

Prominent entities and individuals within the technology and innovation sector, including tech companies, startups, and industry experts. Innovators and creators of digital solutions aligned with the SHAFE concept, driving advancements in technologies that contribute to age-friendly environments. They play a crucial role in funding, developing, and implementing cutting-edge technologies that enhance quality of life.

- **Policymakers**

Government officials, legislators, and regulatory bodies responsible for shaping policies related to digital innovation, healthcare, urban development, and ageing. Policymakers play a critical role in creating an enabling environment for the implementation of SHAFE technologies, establishing regulations, and promoting funding initiatives. They influence funding initiatives, establish guidelines for technology adoption, and create frameworks that encourage collaboration between public and private sectors.

- **Researchers**

Professionals and institutions engaged in research and development, including scientists, academics, and research organizations, contributing to the evidence base supporting digital innovations in SHAFE domain. They explore the efficacy of technologies, assess their impact on health outcomes, and provide valuable insights that guide the development of evidence-based practices.

- **Technology users**

People with diverse characteristics, needs and challenges; community members who directly engage with and benefit from digital innovations within the SHAFE framework. They provide valuable insights into the usability and effectiveness of digital solutions, ensuring that technologies align with the needs and preferences of the population.

- **Healthcare providers**

Medical professionals, including doctors, nurses and other professionals, healthcare institutions, and service providers involved in delivering care. Healthcare providers are crucial stakeholders in the adoption and integration of digital health solutions within the SHAFE concept, contributing to improved healthcare access and outcomes.

- **Community organizations**

Non-profit organizations, community groups, and advocacy organizations focused on issues related to democratic participation, health, and community wellbeing. They play a vital role in bridging the gap between digital innovations and local communities, advocating for inclusivity and ensuring that technologies address specific community needs.

- **Caregivers (and family members)**

Individuals providing care and support to family members or friends. They are integral stakeholders, offering insights into the daily challenges faced and influencing the adoption of technologies that enhance caregiving, wellbeing and support systems.

- **Technology developers**

Engineers, designers and developers involved in creating digital solutions, apps, and devices, bring the SHAFE concept to life. Technology developers are instrumental in translating the SHAFE concept into practical, user-friendly solutions, ensuring that technologies are designed with the needs of users in mind. Their expertise in designing accessible and intuitive technologies is essential for ensuring adoption by users.

- **Advocacy groups**

Organizations and individuals advocating for the rights and wellbeing of people in different situations, promoting inclusive policies and practices. Advocacy groups play a crucial role in influencing policy, raising awareness, and ensuring that the SHAFE concept aligns with broader goals for a happy population.

The collaborative efforts of stakeholders within the digital innovation ecosystem are reshaping the narrative of active and healthy living, ushering in an era where technology serves as a catalyst for healthier, more connected and inclusive life. In the following chapter the continued engagement of industry leaders, policymakers, researchers, and, most importantly, the end-users will determine the success of SHAFE initiatives.

4. STATE-OF-THE-ART AND GOOD PRACTICES

SHAFE envisions environments that are designed to promote the health, wellbeing, and connectivity of all individuals. As we embark on an exploration of the state of the art and good practices in SHAFE implementation, we find ourselves at the intersection of cutting-edge technologies and human-centric design principles.

4.1 General European Union Insights

Digital technologies have pervaded almost all spheres of people's lives, transforming business models, jobs and production, stimulating growth and innovation. The COVID-19 pandemic increased the transformation even further, highlighting its potential for society and the economy: supporting employment, health and education, improving the economic resilience of businesses, and contributing to sustainability [21]

Digital transformation is high on the European policy agenda, being one of the European Commission's main political priorities for the coming years. On 9 March 2021, the Commission presented the **Digital Decade** Communication, which sets a vision and targets for a successful digital transformation of Europe by 2030 [22]. The Commission proposed a **Digital Compass**, which sets out concrete targets for achieving the EU's digital ambitions, evolving around four cardinal points: skills, digital transformation of businesses, secure and sustainable digital infrastructures and digitalisation of public services [23] [24]. Progress towards these 2030 targets is measured by a monitoring system based on the **Digital Economy and Society Index (DESI)** [25].

The European Commission has been monitoring Member States' digital progress through the Digital Economy and Society Index (DESI) reports since 2014. The DESI 2022 reports are based mainly on 2021 data and tracks the progress made in EU Member States in digital (Figure 5). Member States dedicated on average 26% of their Recovery and Resilience Facility (RRF) allocation to the digital transformation, above the compulsory 20% threshold. Member States that chose to invest more than 30% of their RRF allocation to digital are Austria, Germany, Luxembourg, Ireland and Lithuania [25] [26].

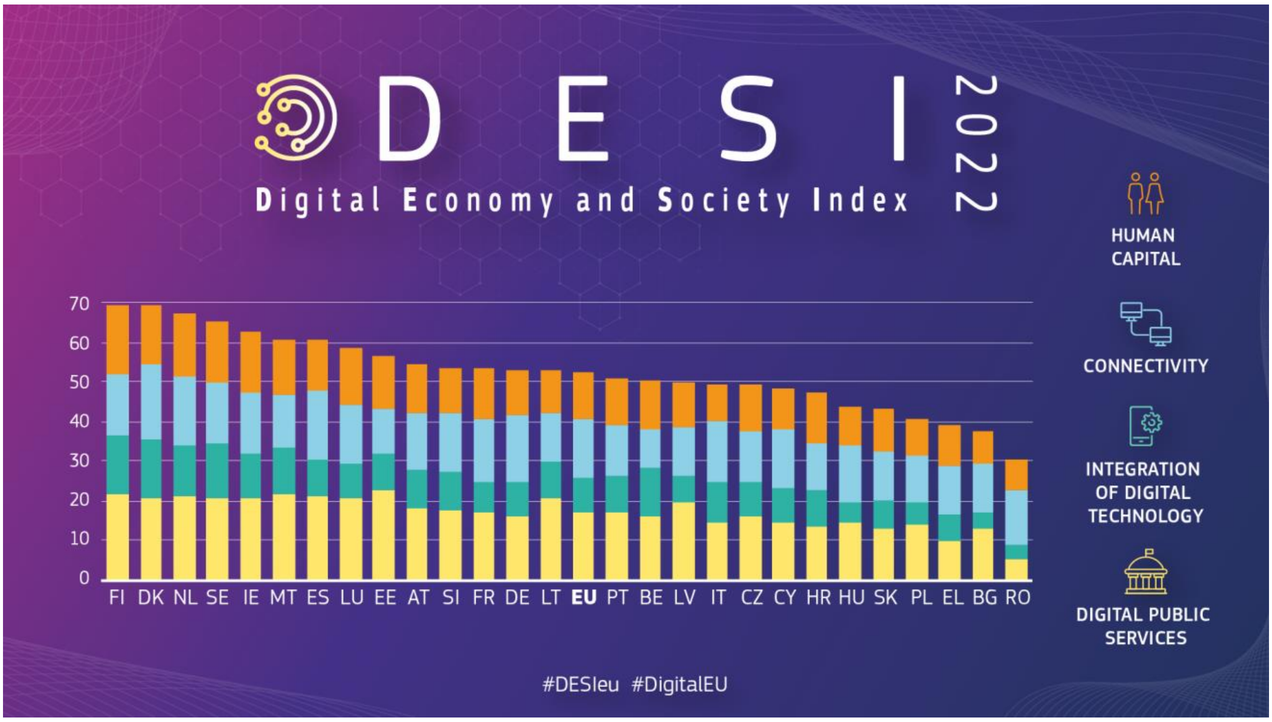


Figure 5 - Digital Economy and Society Index, 2022 [25]

The ambitions set for the area of skills in the Digital Compass are that, by 2030, at least 80 % of all adults should have at least basic digital skills, and that there should be 20 million employed ICT specialists in the EU, with increased women's participation. **In 2021, 54 % of EU citizens aged 16-74 had at least basic overall digital skills.** Digital literacy is crucial for people to benefit from the ongoing digital transformation and the vast variety of services available online, thus preventing them from being digitally excluded. Having digital skills is also critical to protect oneself from cyber threats stemming from the increasingly digitalized world [21].

The highest proportions of people aged 16-74 who had at least basic overall digital skills were found in the Netherlands and Finland (both 79 %), followed by Ireland (70 %), Denmark (69 %) and Sweden (67 %). On the other hand, the lowest were recorded in Romania (28 %) and Bulgaria (31 %). In most Member States, the shares of people with at least basic digital skills were higher among men than among women. In 6 Member States, the situation was reversed, with higher shares of women with at least basic digital skills, with the biggest difference in Latvia and Cyprus. The lowest shares were observed among 65–74-year-olds, where 31 % of men and 21 % of women had at least basic digital skills. The biggest gender gap is visible in the older age groups, where among 65-74-year-olds the share of women with at least basic digital skills was 10 pp points lower than among men in this age group (Figure 6).

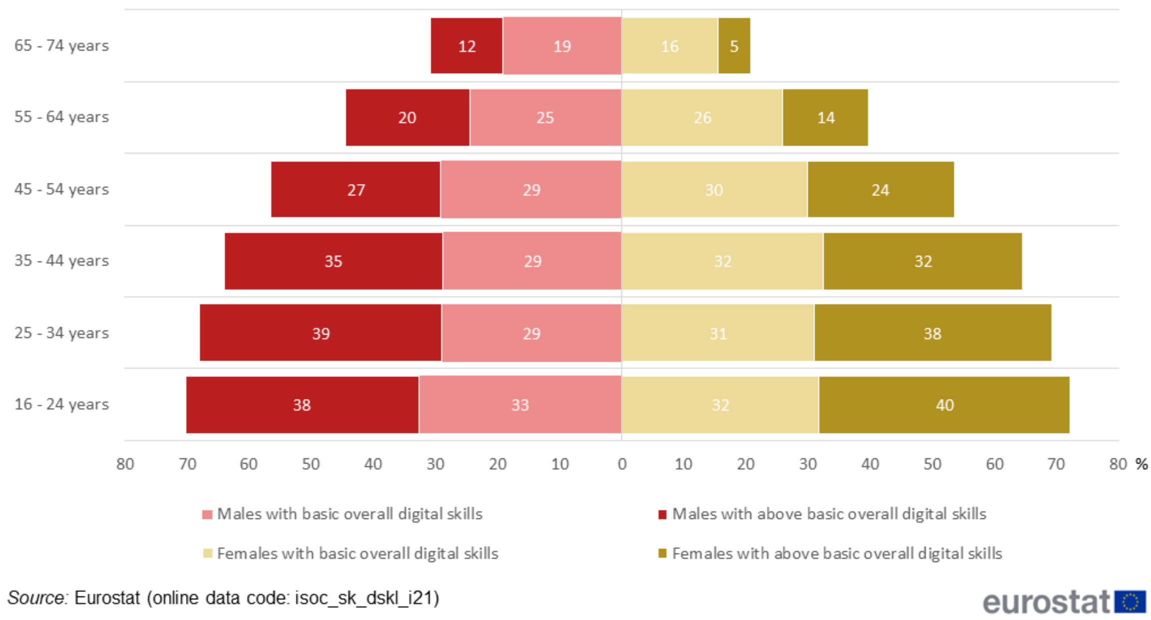


Figure 6 - Individuals with at least basic overall digital skills, by age and sex, EU, 2021 (% of individuals) [21]

The Digital Compass sets goals for the EU's digital transformation of businesses. By 2030, three out of four EU companies should use cloud computing services, big data or artificial intelligence, and more than 90 % of small and medium-sized enterprises (SMEs) should reach at least a basic level of digital intensity. **In 2021, 34 % of EU businesses used sophisticated or intermediate cloud computing services.** The highest shares of sophisticated or intermediate cloud services users among businesses were in Sweden (69 %) and Finland (66 %), followed by Denmark (62 %) and the Netherlands (60 %). In 14 Member States, the shares of enterprises using sophisticated or intermediate cloud computing were below the EU average, with the lowest proportions recorded in Bulgaria (10 %) and Romania (11 %) [21].

Artificial intelligence (AI) can bring many benefits to businesses, such as improved decision-making, productivity or efficiency gains, and optimized and more sustainable energy or resource management. **In 2021, 8 % of EU enterprises used at least one AI technology** - of text mining, speech recognition, natural language generation, image recognition or processing, machine learning (incl. deep learning) for data analysis, technologies automating different workflows or assisting in decision-making (AI based software robotic process automation), technologies enabling machines to physically move by observing their surroundings and taking autonomous decisions. The highest share of enterprises using AI (Figure 7) was recorded in Denmark (24 %), followed by Portugal (17 %) and Finland (16 %), while the lowest shares were recorded in Romania (1 %) and Cyprus, Greece, Estonia, Poland, Hungary and Bulgaria (all 3 %) [21].

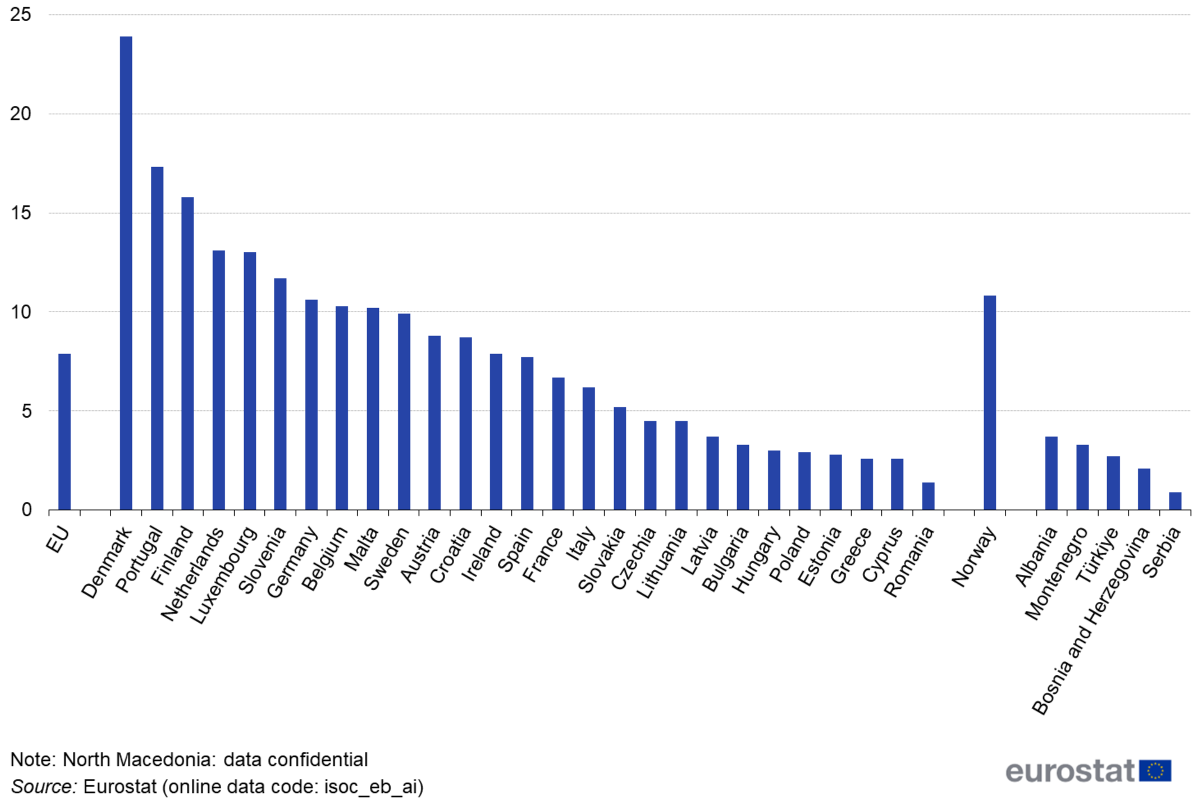


Figure 7 - Enterprises using AI technologies, 2021 (% of enterprises) [21]

All key public services should be available online by 2030, according to the Digital Compass. All citizens should also be able to access their e-medical records, and 80% of citizens should use an eID solution. **In 2021 year, 51% of EU citizens aged 16 to 74 had contacted or interacted with public authorities or services online for personal reasons**. People in Denmark (92%), Finland (91%), and the Netherlands (82%) were the most likely to use e-government websites for things like citizen duties (like filing taxes or letting the government know you're moving), rights (like getting social benefits), official documents (like a birth certificate or ID card), public educational services (like libraries and information on enrolling in schools or universities), and public health services (like hospital services). Germany (33%), Bulgaria (19%), and Romania (14% each) had the least amount of e-government use (Figure 8) [21].

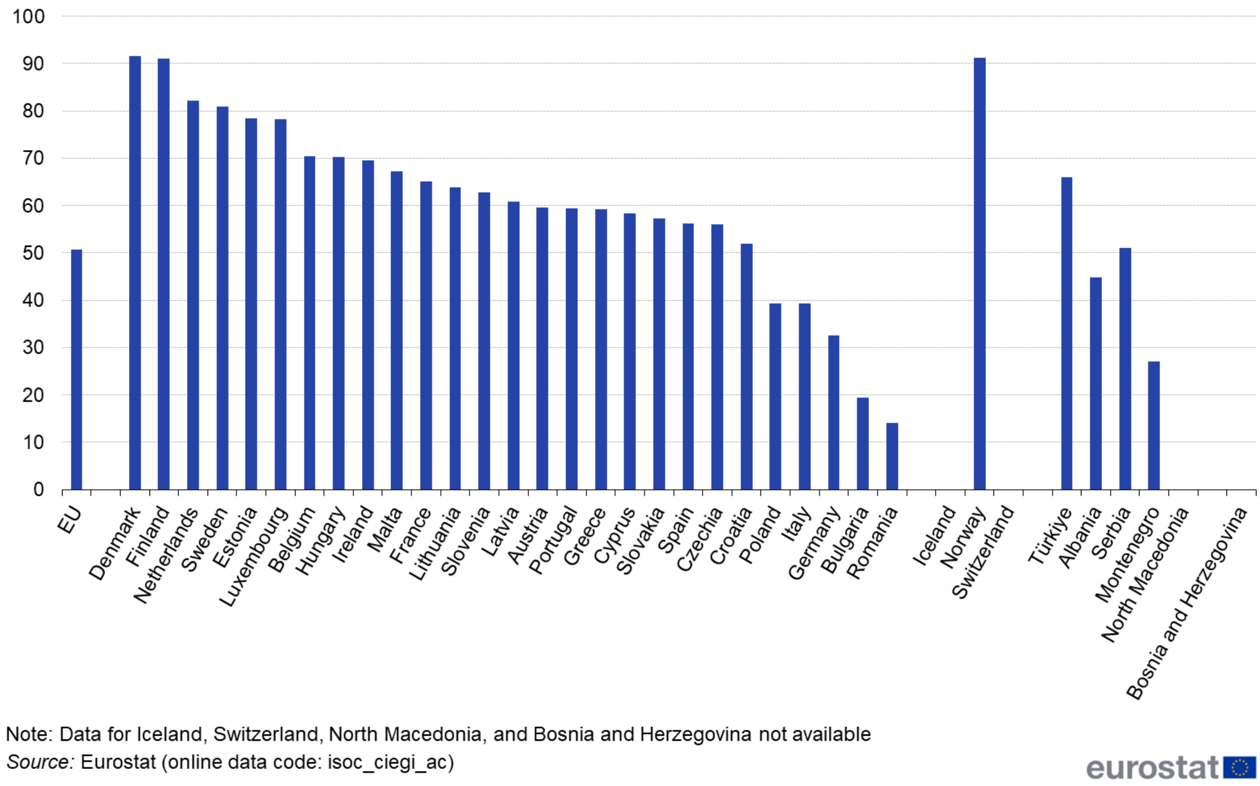


Figure 8 - Individuals who used the Internet for interacting with public authorities, 2022 (% of individuals aged 16-74) [21]

In 2022, 24 % of EU citizens aged 16-74 reported having accessed their personal health records online, 33 % made an appointment with a practitioner via a website, and 52 % of EU citizens were seeking health-related information online. All three rates were highest in Finland, with 81 % of citizens consulting the internet in search of health-related information, 79 % accessing their health records online, and 65 % making a doctor's appointment via the internet [21].

The European Green Deal has made the European Commission start to think about how to make Europe greener. It also brings up the idea of the "digital transition," which is the move to a more digital world. **The Digital Europe Programme** (DIGITAL) is a new EU funding program that aims to help businesses, people, and the government use digital technology. The Digital Europe Programme will help solve the problems by giving strategic funding to projects in next key areas: supercomputing, AI, cybersecurity, and advanced digital skills. It will also make sure that digital technologies are used widely in society and the economy, for example through Digital Innovation Hubs [27].

The Digital Decade Policy Programme establishes a framework for multi-country projects (MCPs), i.e., large-scale projects facilitating the achievement of the general objectives and digital targets. In addition, the Digital Decade Policy Programme introduces the European Digital Infrastructure Consortia (EDICs) as anew means to facilitate the establishment of MCPs. EDICs combine the advantages of a rapid set up, a flexible internal structure and the leading role of Member States in their set up and operations [28]. MCPs have been realized or still realizing with several areas, targeted in all mention documents and initiatives. Selected projects are presented in next several paragraphs.

- **The Pact for Skills** is one of the twelve main actions of the "*European Skills Agenda for Sustainable Competitiveness, Social Fairness and Resilience*" that starts on July 1, 2020. Its goal is to help both public and private organizations learn new skills and improve the ones they already have so they can do well as the green and digital transitions happen. The New Skills Partnership for the Digital Ecosystem helps workers learn new skills and improve the ones they already have as part of the Pact for Skills. It also tries to get more people to work in the digital industry. The Skills Partnership for the Digital Ecosystem began in July 2022 and is now setting the final touches on a work plan and trying to get more stakeholders to join [28].
- **Cyber Security Skills Academy EDIC** will act as an umbrella organization under which different Member States entities would integrate various activities related to cyber security education and training for SMEs, start-ups, and the European public sector, as well as standardization of procedures for cyber security competence recognition and professional certification [28].
- Since the signature of the Euro Quantum Communication Infrastructure (EuroQCI) Declaration in June 2019, the Commission has been working with Member States and with the European Space Agency (ESA) towards the deployment of a secure quantum communication infrastructure - the **European Quantum Communication Infrastructure (EuroQCI) Initiative** - spanning the whole EU, including its overseas territories. In January 2023, 26 national projects, supported by DIGITAL, have begun, with the aim of delivering the design and deployment of the national quantum communication networks that will form the basis of the EuroQCI's terrestrial segment [28].
- **Simpl**, the smart open-source middleware that will enable cloud-to-edge federations and support all major data initiatives funded by the European Commission, such as Common European Data Spaces [28].
- **Common European Data Spaces** are currently being set up in the 14 strategic sectors or domains of Green Deal (including Smart Communities): Agriculture, Mobility, Health, Skills, Manufacturing, Public Administrations, Financial, Tourism, Language, Cultural Heritage, Energy, Media and EOSC (Research). The goal is to have a real single European data market where people can easily access, share, and use data to make new products and services, such as AI tools and technologies. The common European data spaces will include data providers, users, and middle-men like innovation

companies, research institutes, and public administrations. They will include both public and private sector organizations [28].

- **The European Blockchain Services Infrastructure (EBSI)** MCP will use blockchain to build cross-border services that business, citizens, and government agencies can use to check information and make services reliable. Today, every member state plus Norway, Liechtenstein, and Ukraine (as an observer), works with the European Commission on EBSI as part of the European Blockchain Partnership (EBP) [28].

4.2 European digital innovation hubs (EDIHs)

One of the most important tools for solving some of the biggest problems that European businesses are facing is increased digitalization. In order to achieve this, the Member States have established a network of **European Digital Innovation Hubs (EDIH**s), as intended by the DIGITAL Europe Programme, to offer SMEs and public sector organizations (PSOs) in all EU regions and sectors specialized support for digitalization. The EDIH network is currently comprised of 151 EDIHs that are co-funded by the European Commission's Digital Europe Programme and 78 EDIHs with Sea of Excellence. All European Member States plus Iceland, Norway, and Liechtenstein are set to host European Digital Innovation Hubs on their territory [28].

EDIHs help businesses use digital technologies to make their products, services, or business processes better by:

- giving people access to technical help and testing, as well as the chance to "test before invest"
- helping companies deal with environmental issues, especially the use of digital technologies for circularity and sustainability,
- offering services like financing advice, training, and skill development that are essential for a successful digital transformation [29].

An EDIH combines the advantages of being present in a region with the chances that come with being part of a pan-European network. They are in a good position to give local businesses the services they need because they speak the language and understand the innovation ecosystem. The network's coverage across Europe makes it easier for hubs in different countries to share the best ways to do things. It also makes it easier to provide specialized services in areas where people don't have the right skills. The EDIH network web portal has tools to measure how well the EDIH network is working and how EDIHs affect the digital maturity of the organizations they help. Along these lines, the European Commission's Joint Research Center created a Digital Maturity Assessment tool that all EDIHs can use to check on the Digital Maturity progress of their clients. The

Digital Maturity Assessment tool can be found in a part of the website that is only for registered EDIHs [29] [30].

4.3 Digital solutions and interventions in combating social isolation or loneliness

Numerous interventions have been created to address social isolation or loneliness, employing diverse strategies and targeting various aspects such as enhancing social connections or providing services. These interventions are implemented at different levels, including one-on-one interactions or group-focused approaches. Despite multiple systematic reviews assessing the effectiveness of various intervention types for mitigating social isolation and loneliness, the outcomes have occasionally been contradictory [31] .

Digital interventions have garnered significant attention, particularly propelled by the necessity for social distancing and lockdown measures implemented to combat the COVID-19 pandemic. This heightened focus is also attributed to the escalating role that technology, notably the internet, mobile devices, social media, and the Internet of Things (IoT), has played in the past decade or so in mediating social interactions [9] [31]. These digital interventions have found application across various sectors, including healthcare, social services, and community engagement.

Their multifaceted roles encompass digital epidemiological surveillance, swift case identification, community transmission interruption, public communication, as well as the provision of clinical care and support for income and livelihood opportunities during the ongoing COVID-19 crisis [9] [32].

Based on the understanding of the nature and impact of social isolation and loneliness, different strategies have been used in digital interventions to mitigate social isolation and loneliness. Welch and colleagues [9] identified following categories for identifying digital interventions with the aim to reduce social isolation and loneliness:

1) *Interventions to improve social skills*: the goal of these interventions is to help people make and keep meaningful relationships by teaching them interpersonal social skills like how to have a conversation. Some examples are learning how to use computers and the internet to talk to other people or going to an online university for the third age that has classes on how to talk to other people more easily.
2) *Interventions to enhance social interactions*: these are actions that help by making regular contacts, providing care, or being a friend, and by giving advice on how to find and join new groups or activities. Their goal is to help people make and keep social connections. Telecare that helps people make new friends, personal reminder and social management systems (PRISMS), online support groups and forums, social robots or virtual pets, video games, and 3D virtual environments are some examples.

3) *Interventions to enhance social support*: these are interventions that aim to make relationships better and give people more chances to interact with others. They aim to help people stay in touch with family, friends, and the community. Examples include online chat rooms, social networking sites, discussion forums and online chat rooms, and phone befriending. Authors [9] considered telephone befriending an intervention to improve social interactions because the main goal of the service is to connect regularly and build a friendship with an older person. Telephone befrienders could also offer social support [31].
4) *Interventions for social cognitive training*: these are actions that try to change the way people think and feel negatively about social relationships. Their goals are to change behaviours, lessen harmful thoughts, and make more social connections. Low-intensity psychosocial interventions, cognitive behavioural therapy (CBT) delivered over the internet, and mindfulness interventions are some examples.

The same authors [9] considered four mechanisms than can be used to achieve the impact of digital interventions:

- Offering assistance in developing skills for social interactions, such as providing training in computer and internet usage and offering online educational programs.
- Sustaining existing relationships through activities like video chatting with family and friends, using a personal reminder information and social management system (PRISMS) to involve loved ones in caregiving.
- Establishing new connections through initiatives like telephone befriending programs, social networking platforms, interactive robots and virtual pets, and video games.
- Modifying negative social thinking patterns, for instance, employing online cognitive behavioural therapy to help lonely individuals recognize and overcome negative thoughts and emotions related to their relationships, such as feeling a lack of intimate attachment to friends or family [9] [32].

This evidence and gap map [9] has 200 included articles and there are almost as many primary studies (n = 103) as reviews (n = 97), with most conducted in the Americas, the European and Western Pacific regions. The evidence is unevenly distributed across intervention and outcome subcategories with a similar trend across primary studies and reviews. The majority of included primary studies and reviews assessed digital interventions to enhance social interactions with family and friends and the community via video conferencing and telephone calls. Digital interventions to enhance social support, particularly socially assistive robots, and virtual pets were the next most assessed subcategory of interventions. The social cognitive training strategy was the least assessed of the four intervention strategies although it is considered the most effective. The most assessed outcomes were reducing loneliness and depression and improving the quality of life of older adults. Only six reviews reported adverse events and two on-going primary studies planned to report adverse effects. The most reported age range was 70-80 years old and most common needs addressed were social and emotional needs [9] [32] [33] [34] [35].

4.4 Analysing the existing examples of innovative projects

Digital innovation encompasses a wide range of technologies and approaches that are transforming industries, lifestyles, and societal frameworks. The field of digital innovation has been rapidly evolving and needs to consider the many aspects of user acceptance, especially when it comes to using different kinds of technology, like computers, assistive devices, and email programs. Acceptance of technology is affected by age, gender, how much you know about its history, and how you feel about using it. There are two main parts to technology acceptance models: how useful and how easy to use something is seen to be. This is why educating people, making ICT easy to access, and using technology in the right way must be part of any plan to reach people, especially those in vulnerable situations [8] [15].

Adopting technology is a key part of making sure that people can use technology. Almost every part of work and life depends on being able to use technology. From filling out a government form to talking to people at work, it's hard to think of a task or job that doesn't require some basic digital skills. Policies that are meant to help people get used to the Internet need to take into account how they learn and live their lives, as there is no "one-size-fits-all" answer [15].

The goal of learning activities should be to boost confidence and get rid of fears about using new technologies. We need sales advice that is both fair and understanding about the best devices and packages, as well as help with learning. When people use educational services, they can better enjoy their life. Often, the best way to get new technology products on the market is through educational programs like training. Because of this, training is likely to be an important part of getting people to use technology, including policies and programs that cover all of the above aspects of connectivity, ICT accessibility, and adoption [8].

Information and communication technologies (ICTs) can facilitate a healthier living, helping people live with better-quality and for longer. Digital health platforms, such as e-health and associated mobile (m-Health) and telemedicine platforms, have brought digital technologies into widespread use for health-related purposes in a wide range of settings, both inside and outside of hospitals and clinics. The World Health Organization (WHO) has defined e-health as any use of ICTs for health. Given the proliferation of digital devices for personal and business use, digital technologies have become an essential enabler in treatment and prevention strategies. For example, wearables and fitness devices can provide continuous monitoring and prevention as patients go about ordinary daily activities. Enhancing digital health capabilities aligns with UN Sustainable

Development Goal 3 (Good health & wellbeing) and helps people and communities everywhere achieve healthy ageing [15].

Previous desk research study within establishing SHAFE Thematic Network identified five main areas [2]:

- Wellbeing and Quality of Life
- Healthcare delivery and prevention
- Independent living and age-friendly environments
- Ethical and privacy issues: Healthcare professional in a new role
- Efficiency and efficacy

Beside the research in scientific literature, European funded projects are identified based on topics such as 'eHealth', 'mHealth', 'telemonitoring', 'age-friendly environments', 'independent living', 'ageing in place', executed for or suitable for people with chronic diseases and/or impairments. European funding programmes are FP6, FP7 and Horizon 2020 and databases: CORDIS and INNORADAR [2]. Results are presented within the boxes at the end of each area, using projects acronyms and selected projects are presented with more details. The existing base was published in 2018, so the updated information as provided within text, as well as within list of projects. It provides the update and improves data collection with contemporary information to gather current and relevant information on digital innovation related to SHAFE areas.

Wellbeing and Quality of Life

Understanding quality of life (QOL) is relevant for improving care, symptom relief, and rehabilitation of patients [36]. Patients' self-reported QOL may reveal problems that can lead to modifications and/or improvement in treatment/care or may indicate that some treatments or practices offer little or no benefit. QOL has become a significant target for research and practice in the fields of health and medicine [37]. Traditionally, medical outcomes have been the principal endpoints in medical and health research. However, in the last decades, more research has focused on patients' QOL [36].

Sharing and gathering information on QOL in different diseases can be used to identify the range of problems experienced by the patients. This kind of information can be helpful to future patients to understand their disease and the treatment pathway, as well as to long-term survivors facing problems long after their treatment is completed. Moreover, QOL is a predictor of treatment success, thus has a prognostic importance, shown to be strong predictor of survival [37].

Despite QOL importance in medicine and general health, there is still an ongoing methodological debate on meaning of QOL and how is to be quantified, i.e. measured. The World Health Organization (WHO) offers a definition of QOL; "*An individual's perception of their position in the in the life in the context of the culture in* *which they live and in relation to their goals, expectations, standards and concerns*" [38]. While the health-related quality of life (HRQOL) is described as:

"A term referring to the health aspects of quality of life, generally considered to reflect the impact of disease and treatment on disability and daily functioning; it has also been considered to reflect the impact of perceived health on an individual's ability to live a fulfilling life. However, more specifically HRQOL is a measure of the value assigned to duration of life as modified by impairments, functional states, perceptions, and opportunities, as influenced by disease, injury, treatment and policy" [39].

Technological advances are an important support to QOL improvement, as facilitators of digital health and a new patient centric paradigm of healthcare. These solutions do not only improve diagnostic, treatment monitoring, management, and delivery of healthcare services, but as well offer a platform to alleviate the standard of care supporting people with (chronic) diseases or impairments to improve quality of life and wellbeing.

E-health has become an integral part of the healthcare systems changing the management of data, service appointments and delivery, treatment prescription, and health monitoring, leading to more efficient workflows at all levels, less errors and more efficient and timely treatment [40]. For example, the use of electronic medical records, with all patient information stored centrally, prevents inappropriate prescription and administration of medication during medical care and ensures more efficient treatment and insight into patient medical history [41]. The success of e-health in a country is related to four stakeholders involved in the process: entrepreneurs/public health governing bodies, healthcare professionals, patients, and the bodies responsible for health insurance and assistance policies [42]. To implement information technologies in healthcare, e-health strategies have to occur in an integrated manner, by development of norms, laws, or regulations.

Mobile health or mHealth consists of the use of mobile devices so that patients can solicit services electronically, use apps to verify information, and manage or monitor treatment or problems or other health-related issues [43]. Telehealth assumes the use of telecommunication technologies to promote the care and health related education of patients and healthcare [44]. The potential of health has continuously been driven by are three factors: (a) growth in mobile technologies and applications, (b) new integration technologies and (c) a widespread coverage of mobile phone networks [45].

The use of mHealth can extend the reach of healthcare, especially in the domains where specialized expertise is required, otherwise unavailable in rural areas. Digital health and use of applications on mobile devices offer possibility for distant interaction between patient and therapist, communication within patient groups and support related to care and QOL advice. In such a way patients feel more confident and empowered, being in control of their health in an efficient way. health contributes to the more effective decision-making, reducing the reaction time for appropriate action. At the patient side mHealth operates through different clinical application powered by external sensors for condition and lifestyle monitoring to ensure safe and reliable decision making and care [46].

Around 2.5 billion people worldwide own a mobile phone opening a huge potential for mHealth and unprecedented access to clinical diagnostics and treatment advice [47]. In the US 56% of physicians talked about mHealth with patients and 26% have been asked about mHealth by a patient (PWC Provider Survey) [47]. mHealth brings the largest improvement margin to the people in rural and developing areas, due to the long time needed to ensure service delivery. It can overcome the lack of diagnostic infrastructure availability and expertise at local community levels, as long as smartphone adoption in rural areas is rather similar to that of urban or developed areas [48].

There are numerous projects within H2020 pillar SOCIETAL CHALLENGES - Health, demographic change and wellbeing that deal with quality of life and wellbeing (Table) usually tailored for specific diseases that represent a heavy burden both to patients and caregivers. We will demonstrate selected examples, to obtain a full perspective of technical complexity of setting in place a clinical mHealth application, improvements in wellbeing that it brings, user acceptance and social impacts it might have.

Identified EU projects for wellbeing in CORDIS and INNORADAR (by acronym)		
EU-WISE	BETTER AGEING	Smart4Health
EU-GENIE	IMANAGE CANCER	**MENHIR**
SOUND OF VISION	MY AIR COACH	GATEKEEPER
RICHARD	DECI	**SmartEater**
NEBIAS	NEPRHON+	**MOBILIZE**
ACTION	AALUIS	**MindCare**
SIMPLESKIN	CO-LIVING	**LOCOMOTION**
RECALL	CAPMOUSE	**Smart-BEEjS**
SIFORAGE	CONNECTED VITALITY	**PaCE**
EGOVISION4HEALTH	EXPRESS-TO- CONNECT	**EMPOWER**
OPTIFEL	FEARLESS	**TIMELY**
SIGNS FOR EUROPE	INCLUSION SOCIETY	**TeleRehaB DSS**

OTOSTEM	BD4QoL	**ADLIFE**
SOCIAL ROBOT	VITAL	**R2D2**
DISCIT	MDS-RIGHT	**IN-4-AHA**
VALUE-AGEING	DIAdIC	**EUonQoL**
SILVER	PreventIT	DynaMORE
TEC FOR LIFE	**TeNDER**	X-eHealth

Table 1 - Wellbeing projects CORDIS [49]and INNORADAR [50]

BD4QoL (Big Data Models and Intelligent tools for Quality-of-Life monitoring and participatory empowerment of head and neck cancer survivors) is an H2020 project ending in 2024 that focuses on quality of life in Head and Neck Cancer (HNC) patients, as it imposes a high socioeconomic burden on patients during and after cancer, including costs from treatment-induced morbidities, loss of workforce participation and short-term disability. All of these factors can have a negative influence on emotional wellbeing, within family interactions, loss of work, stigmatization, and social integration, especially for women. BD4QoL addresses survivors' and physicians' needs and overcomes the cultural, psychological, organisational, and technological barriers to systematic and coordinated monitoring of QoL in HNC survivors. BD4QoL relies on mobile technologies, e-coaching tools (chatbot) and AI to provide for unobtrusive and continuous collection and monitoring of QoL variables and the delineation of personalized QoL trajectories (

Figure 9). The main outcome is a platform (Figure 10) for monitoring HNC survivors that integrates set of the following tools:

- a mobile app collecting indicators of physical activity, sleep, social activities (Figure 11);
- a chatbot for patients' support and empowerment in self-management of their QoL daily issues and treatment sequelae, tailored and physicians' driven information
- a web-based tool for point of care physicians allowing individual survivors' monitoring and early identification of QoL deterioration from the analysis of the indicators collected from patients, linked to a data management tool (REDCap)
- a web app that allows the collection of individual QoL questionnaires
- advanced models for personalized QoL prediction that will allow profiling of survivors and tailoring the follow-up strategies and post-treatment support.

This project includes evaluation of the developed platforms in a randomized controlled trial (RCT) involving 420 HNC survivors in Italy and UK, that would provide a useful feedback from a user perspective on usefulness and improvement brought by the designed tools.

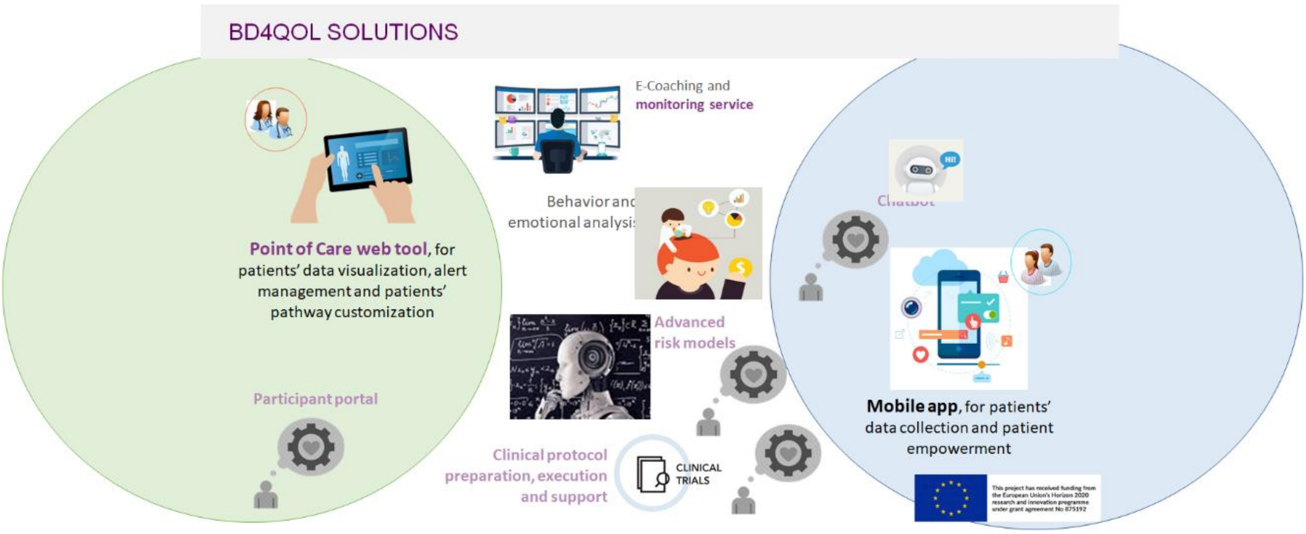


Figure 9 BD4QoL solutions for Quality-of-life monitoring after head and neck cancer (source)

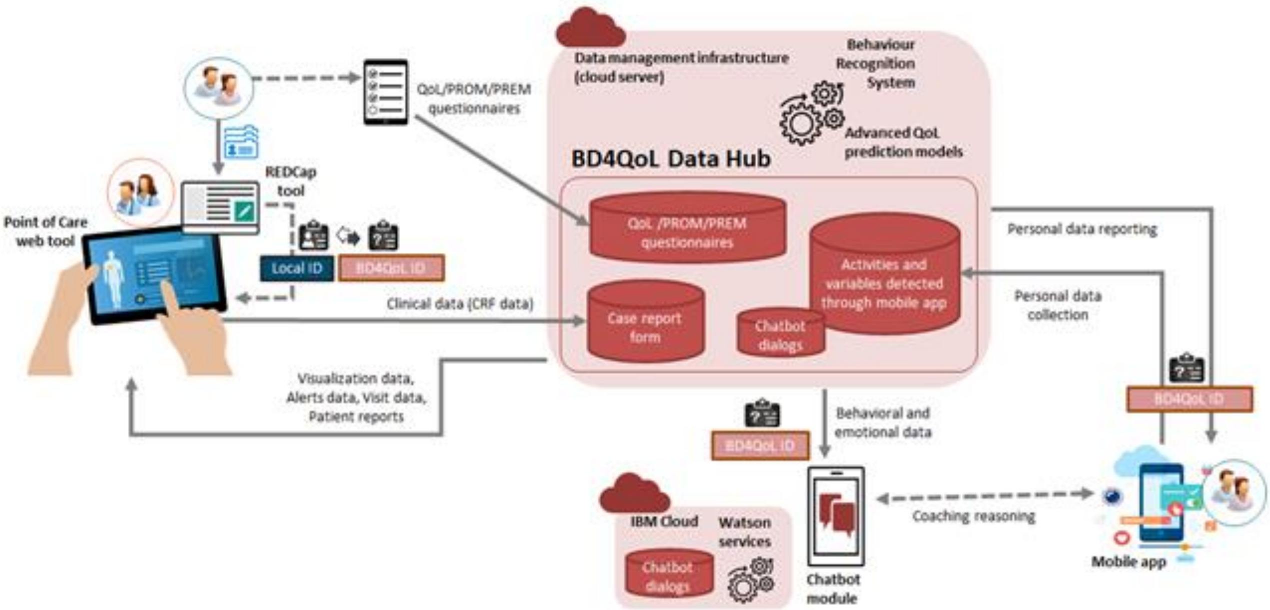


Figure 10 - BD4QoL functional architecture (source)

Figure 11 - Mobile apps for QoL indicators collection (source)

The exemplified mHealth tool BD4QoL illustrates potential to offer guidelines to a chronic patient in their lifestyle and deliver personalised care. Patients can improve their knowledge on their disease and connect patients with the same pathology in groups, providing support and motivation to each other [51].

EMPOWER (*European platforM to PromOte Wellbeing and HEalth in the workplace*) project (2020-2024) will investigate and test the impact and cost-effectiveness of a compatible eHealth intervention platform aiming to prevent common mental health complications and reduce psychological distress in the workplace. The platform will be created in collaboration with stakeholders and direct employees and employers of SMEs and public institutions in Finland, Poland, and Spain. The project will apply both qualitative and quantitative methods to assess personal effects, cost-effectiveness, and potential obstacles to detect the major challenges on both an individual and organizational level [52]. It is a multidisciplinary research and innovation effort aiming to developing, implementing, evaluating, and disseminating the effectiveness and cost-effectiveness of a modular eHealth intervention platform to promote health and wellbeing, reduce psychological distress, prevent common mental health problems and reduce their impact in the workplace. The Empower anti-stigma campaign consists of anti-stigma material and psycho-educational material focusing on stress at work and all you need to know about creating a better working environment. EMPOWER will develop a multi-modal and integrative eHealth platform aimed at reducing mental health problems in the workplace and improving employees' wellbeing.

The triage design for the EMPOWER app targets symptomology of individual users and is based upon validated risk assessment questionnaires. The resulting protocol (Figure 12) allows for variations in support level and material offered depending on participant need as well as specific modules to address comorbidity. This design provides an innovative approach to addressing workplace mental health concerns and targeted support of employees as well as managers and employers for work related problems, unlike most digital interventions on the market currently that focus on employees only [52] [53].

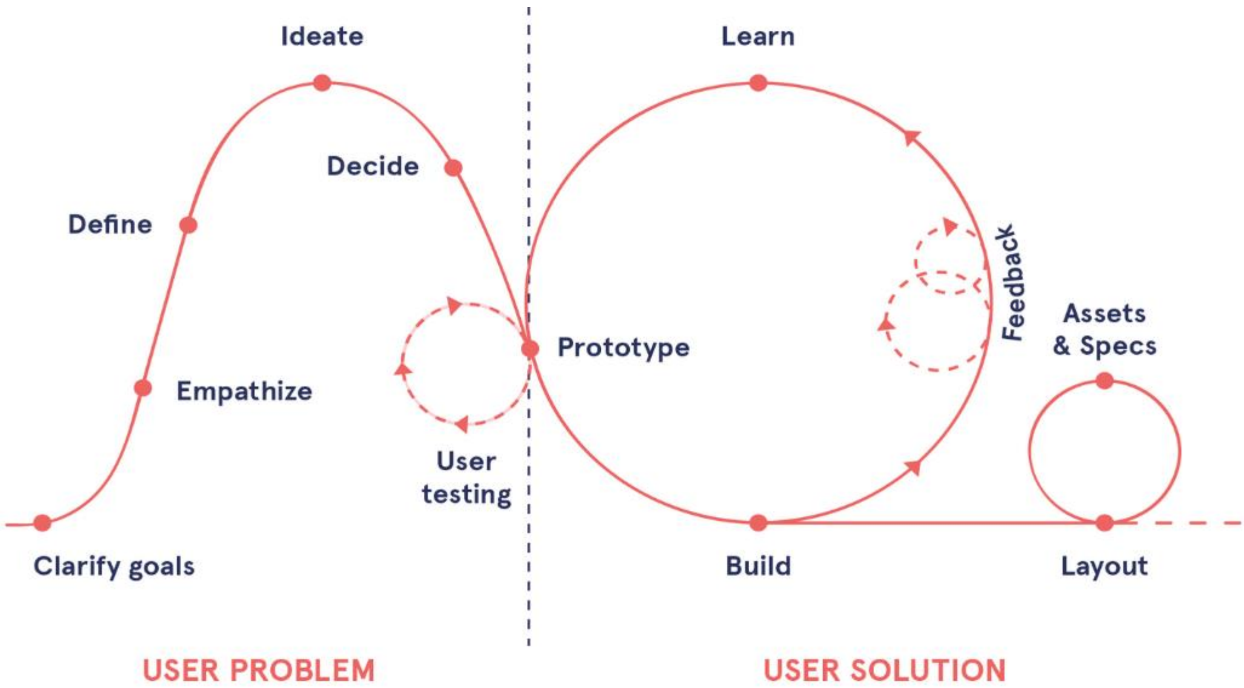


Figure 12 - Agile design process as used for the app.

In conclusion, mobile applications have the potential to be transformed into powerful platforms for delivery of behaviour change interventions because they can improve engagement with established strategies for prevention and treatment of disease through personalized goal setting, individualized dosing reminders, and gamification [54]. In a daily life, applications linked to wearable devices monitoring heart rate and activity level often utilize some behaviour change techniques centered on social cognitive theory such as: comparison and competition between users, self-monitoring, and review of physiological changes [47]. A review published on studies investigating the effect of mobile apps to improve weight loss and physical activity indicate reductions in BMI of 0.43 kg/m2 (95% CI −0.74 to −0.13) with much greater weight loss seen when the devices were used optimally [55].

mHealth apps can have educational value to patients offering easily accessible structured disease and treatment-related education to the user [47]. In the study [56] randomized patients with knee pain were offered an educational app with structured interactive content or no intervention prior to attending a specialist. It was shown that application had improved the level of actual disease-related knowledge at clinical attendance by 52% and the perceived knowledge by 22%. The applications that impact most QoL and wellbeing are those that can broaden the availability of services through ease of access (reducing inequalities and patient frustration), and those improving the user satisfaction.

Despite mHealth application have a great potential, the level of evidence of their use in clinical workflows is modest. However, the interest from both patients and NCP is growing but there should be more clinical guidance on how mHealth apps should be utilized to add value to patient care, in terms of improvements in speed and accuracy of diagnosis, personalized treatment regimes, behavioural change advice, patient education or improved access to established therapies such as cognitive behavioural therapy [12].

Moreover, in using teleservices, the issues of user adherence and user acceptance can be raised. The balance should be stroked between the level of additional effort needed to provide a feedback to HCP, and actual benefits as perceived by the user. mHealth applications usually rely on data collected by wearable devices. The seamless integration of wearables into consumers' electronics is well witnessed throughout the Consumer Intelligence Series on wearables from 2014 and 2016 [18] [19]. According to these sources, numerous user concerns such as design, accuracy, reliability, security, privacy and dampened human interaction are becoming less worrying to the users. Research on sensor materials and communication solutions can provide advances in human-centered design and enhance the user-experience.

Another issue related to wearable systems deployment in real world concerns technology acceptance. Even though wearables are adopted by the millennials, older population is still uncomfortable with using, and even more relying on technology. The use of wearables in fitness and wellbeing scenarios does not have the clear usage need and benefits, as opposed to smartphones for example. Consumers complain on uncomfortable and unattractive design, short battery life, and frequent connectivity challenges [19].

Healthcare delivery and prevention

eHealth tools commonly include remote or home telemonitoring, web and computer-based interventions, virtual reality tools, and use of sensors. These tools can include questionnaires, video recording or games, and be used for the purpose of gaining more clinical data, better decision making, and increasing healthcare accessibility [57].

Systematic reviews of published evidence on eHealth usage between 2014 and 2019, report that the most commonly treated diseases are mental illnesses, multiple diseases (diabetes mellitus 1 and 2, stress, depression, and anxiety), cancer, eating disorders, chronic illness, cardiovascular diseases, and sexually transmitted diseases [40]. These studies have been conducted in the following countries: United States, Canada, Australia, Germany, Sub-Saharan Africa, Africa, Netherlands, Sweden, Switzerland, China, Italy, Greece, Finland, Iran, Iraq, Bangladesh, Pakistan, Saudi Arabia, United Kingdom, Spain, France, Italy, and Portugal.

By the popularity and usage there are two main categories of autonomic diagnostic application in mHealth: (1) symptoms checker applications and (2) applications using sensor data to screen health (photos or other embedded sensor readings) [47]. By the recent studies, more than 50 million people worldwide use app-based self-triage and interactive symptom checkers are the most frequently investigated category of diagnostic applications [58]. The research has been conducted on 23 prominent symptom checker which indicated that in 80% of emergency cases the advice was appropriate (the percentage is comparable to that seen from junior doctors) [59]. The diagnostic accuracy decreases in non-emergency cases to 34% and triage advice was considered appropriate in only 55%.

The autonomic diagnostic applications that use sensor readings, mostly photos often rely on expert and data driven knowledge and AI algorithms. In a systematic review encompassing 30 studies, diagnostic potential of 35 applications intended to analysis of images of melanoma (skin changes) or tremor diagnoses by analysis of movement has been evaluated [60]. The diagnostic sensitivity was estimated at 82% (95% CI 0.56–0.94), and pooled specificity at 89% (95% CI 0.70–0.97) [59]. However, oncology experts consider that the current diagnostic sensitivity is still not enough to replace the expert clinical examinations [61].

The spectra of technology applied to healthcare includes Internet of Things (IoT) to integrate medical sensors, cryptography and security (authenticate, encrypt and maintain security and data confidentiality), cloud systems facilitating data storage at a low cost while also being secure and private and use of Big Data for analysis, diagnosis, and treatment of diseases [62]. The medical sensors can be embedded in smartphones, external devices, integrated into clothing as smart textiles or placed under the skin [63].

Identified EU projects for 2 *Health delivery and prevention* in CORDIS and INNORADAR (by acronym)		
FARSEEING	PRECIOUS	**SMART BEAR**
ISTOPPFALLS	PEGASO	**BOOST HEALTH**
DEM@CARE	PERSSILAA	**SCUBY**
MATSIQEL	PREVENTIT	**D2P**
HEALTH-ON-THE-MOVE	MY-AHA	**EIS**
COOLNESS	GIRAFF+	**PRO-TOOLKITS**
CARDIOPROOF	ACCESS	**TICARDIO**

DOREMI	ICT4LIFE	**ROBUST**
EURO-URHIS	APA	**EarlyCare**
UNCAP	PRIMER COG	**CARDIOCARE**
FOODSMART	SPOTLIGHT	**WILLEM**
SWORD	RECALL	**MyPath**
REHAB@HOME	**ESCAPE**	**PANCAIM**
PASTA	BigData@Heart	**ProCAncer-I**
V-TIME	ICU Care	**AICCELERATE**
IROHLA	HEARTEN	SHIFT-HUB
EUROBATS	A-WEAR	RES-Q PLUS
I-DON'T-FALL	LUCINE	**HumanITcare**
WALKX-ROBOT	**EXA MODE**	PERSIST
HELENA	**NORATEST**	
VELOINFO	**bio-T**	

Table 3 - Health delivery and prevention related projects [49] [50]

Big data has a significant potential for healthcare in extracting knowledge hidden in data. As a result of the exponential growth in medical data collection, there are large datasets with different kinds of data usable for healthcare [63]. With large amounts of good quality data, AI models can be learned to facilitate powerful tools for assessment of a patient's medical record, evaluation of medical evidence, and even suggestion of potential treatment options.

The power of big data analytics has been used in many research projects to support advanced diagnostics, especially relying on genetics disease signatures. The genomics revolution has already brought personalized medicine to cancer and rare diseases, and EU project **BigData@Heart** is one of the examples where genomics data will be combined with traditional cardiovascular markers with ultimate goal to develop big data-driven translational research platform of unparalleled scale and phenotypic resolution. The research platform should deliver clinically relevant disease phenotypes, scalable insights from real-world evidence driving drug development and personalized medicine through advanced analytics. The research is motivated by the need to improve the management of cardiovascular conditions due to their complex aetiologies, poor definition at the molecular level, and the added burden of co-/multi-morbidities. This leads to unpredictable and large variations in interindividual therapeutic response, heterogeneous prognoses, and treatment guidelines that are based on conventional risk factors and clinical markers of end-organ damage (BigData@Heart).

The AI based data analytics can further be used to improve health delivery at the most critical ICU hospital units, with the vast daily costs (in Europe €26Bn is an annual ICU cost of severe patients). EU H2020 projects **ICU Care** has developed BEACON Caresystem – a novel ICT-based ventilation assist system, offering better ventilation strategies and a more efficient patient care workflow. BEACON Caresystem is an add-on to standard ventilation systems providing ventilation recommendations 24/7 based on unobtrusive, personalized monitoring of patients (Figure 13). Physiological models and analytical algorithms facilitate delivery of recommended weaning off scenarios, supporting the critical decision-making processes. The BEACON Caresystem should reduce the Length of Stay (LOS) with 15-25% – cutting ICU costs with the proportional amount (ICU Care).

Figure 13 - BEACON Caresystem as an add-on to traditional ventilation systems (source)

As heart failure (HF) is a vast clinical and public health problem, related with significant mortality, morbidity, and healthcare expenditures, especially with ≥65 years, many projects address remote monitoring, disease management and assistance to HF patients. EU project **HEARTEN** offers a collaborative environment for the

HF management procedure by providing new enhanced capabilities to all involved actors, patients, caregivers, HCPs, nutritionists, physical exercise experts and psychologists (Figure 14).

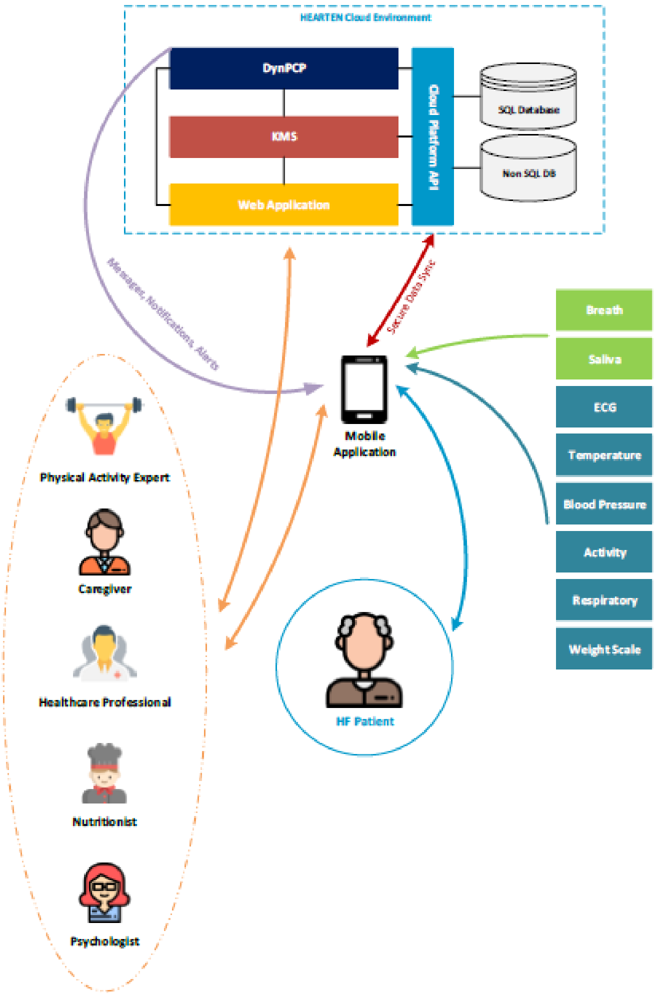


Figure 14 - HEARTEN collaborative environment (source)

Some barriers to e-health include technology readiness and acceptance considering the level of difficulties faced when using systems and applications. Interoperability across systems is another major challenge in e-health hampering the interaction with the previous health information systems and communication between the hospitals. Moreover, the cost of implementing e-health is very high due to the high levels of investment required to purchase equipment to implement digital health services, technical support and ensure security and privacy of data storage and in data transmission [40].

Despite the current limitations of diagnostic mHealth apps there is huge potential and evidence is starting to emerge to demonstrate clinically significant improvements in morbidity and mortality outcomes in specific scenarios. The World Health Organization already advises that digital diagnostic platforms may be valuable for patients in low- and middle-income countries where expert clinical advice is difficult to access [64].

It is very likely that in the future mHealth apps will be integrated into established clinical treatment pathways, in order to improve the outcomes and increase access to specialized therapies [47]. The health data collected by mHealth apps can be used to recognize early signs of disease support technology-assisted clinical decision making. For example, there are already connected mHealth technologies that can accurately detect conditions such as atrial fibrillation. mHealth technologies empower patients to manage their own health providing additional benefits to healthcare delivery systems (Table 4) [47].

Population level value for each category of mHealth app	Broaden availability of services through ease of access, reduce inequalities	Cost-effective (low marginal cost, highly scalable, early detection, prevention rather than cure)	Cost-effective (reduce human resource burden on healthcare system by enabling patient driven care)	Improve patient satisfaction through better communication with healthcare providers	Green & sustainable
Diagnostics and clinical decision-making apps	yes	yes	yes	no	yes
Behaviour-change apps	yes	yes	yes	yes	yes
Digital therapeutic apps	yes	yes	yes	no	yes
Disease-related education apps	no	yes	yes	yes	yes

Table 4 - Potential future value propositions for mHealth apps [47]

Independent living and age-friendly environments

Independent living refers to the degree to which older people have the autonomy to control and lead their own lives, even if they do not do everything by themselves [65] It depends on many aspects, including economical, such as accessible housing, home automation, availability of continuous care or support, outdoor environments. In this report we focus on technology as one of the important facilitators of independent living and age-friendly environments coupled with eHealth and mHealth frameworks of digital health.

The decrease in physical activity is considered to be in high correlation with ageing, associated with low social function, and cognitive decline. A focus on physical, social, and cognitive activity is needed in order to promote active and healthy ageing, and to permit people to live independently for longer. Active Assisted Living (AAL) technologies support older people keeping people connected, healthy, and active, into their old age. AAL concerns the development of services and products that should improve QoL and wellbeing of older ageing population and their caregivers [66].

The integration of technology in the home environment creating ambient assisting living has the potential to increase independence [67]. Development of the healthcare system infrastructure in remote settings is supported by the wide data transmission network outreach and local use of wireless sensor networks. Internet technologies support communication and exchange of data with different objects through embedded sensors and supporting technology leading to Internet of Things (IoT). The IoT concept provides for pervasive and seamless monitoring without interoperability challenges overcomes in terms of mHealth, IoT brings a new concept for information gathering and exchange which bridges interoperability challenges [68] .

Offering ambient-assisted living services depends on multiple factors, commonly not related only to technology, but as well, among many, to economy related facilitators that influence network coverage, availability and affordability of ICT infrastructure, technology acceptance by HCP and end users. Ageing-in-place has been promoted by policymakers as the optimal residential solution for later life. The convergence of IoT and healthcare has enabled self-caring, event detection such as seizure detection, fall detection, stroke rehabilitation, neurologic and cardiac monitoring [67]. Home environments should be adaptable and accommodate losses in physical and social function. In the context of home automation, new technologies can improve the QoL, providing easy access to many functions remotely, or allow the use natural language processing and computer vision in order to control lighting, climate, appliances, and other in-house systems.

Identified EU projects for independent living in CORDIS and INNORADAR (by acronym)		
MARIO	MY LIFE	GATEKEEPER
SILVER	ROSETTA	**HARPER**
ALFRED	AUTONOM@DOM	**5G-TOURS**
JADE	LIFE LONG LIVING	**SMART BEAR**
INNOVAGE	ANDALUSION TELECARE SERVICE	**WorkingAge**
AQB-CARE		Ageing@Work
COMPATABILITY	CARPETSYSTEM	**SmartWork**
HOMECARE	GROWMEUP	**AGRUMIG**
IBENC	My-AHA	**SMILE**
REAAL	IN LIFE	**DigiCare4You**
ACCOMPANY	PHArA-ON	**e-VITA**
PRO ACT	**IDIH**	SEURO
MIRACULOUS LIFE	**VALUECARE**	**PROCare4Life**
USEFIL	**INADVANCE**	
CITY4AGE	**eCARE**	

Table 5 - Independent living and age-friendly environments related projects

There are numerous European initiatives and projects promoting solutions to support independent living and age-friendly environments (Table 5). My Active and Healthy ageing (**my-AHA**) is H2020 project that developed an improved methodology for detecting risk, yielding a new cumulative frailty index. The methodology used relies on fitness monitoring devices with ICT tools developed within project. The system provides personalized assessment and intervention strategies to support active and independent living among older adults.

The main part of the my-AHA system is the middleware that integrates information from various existing and future platforms (Figure 15). myAHA has developed and tested new models that predict risk of developing frailty. The system and new frailty index have been validated in a major study involving more than 200 participants from seven EU countries, Japan and Australia (my-AHA)

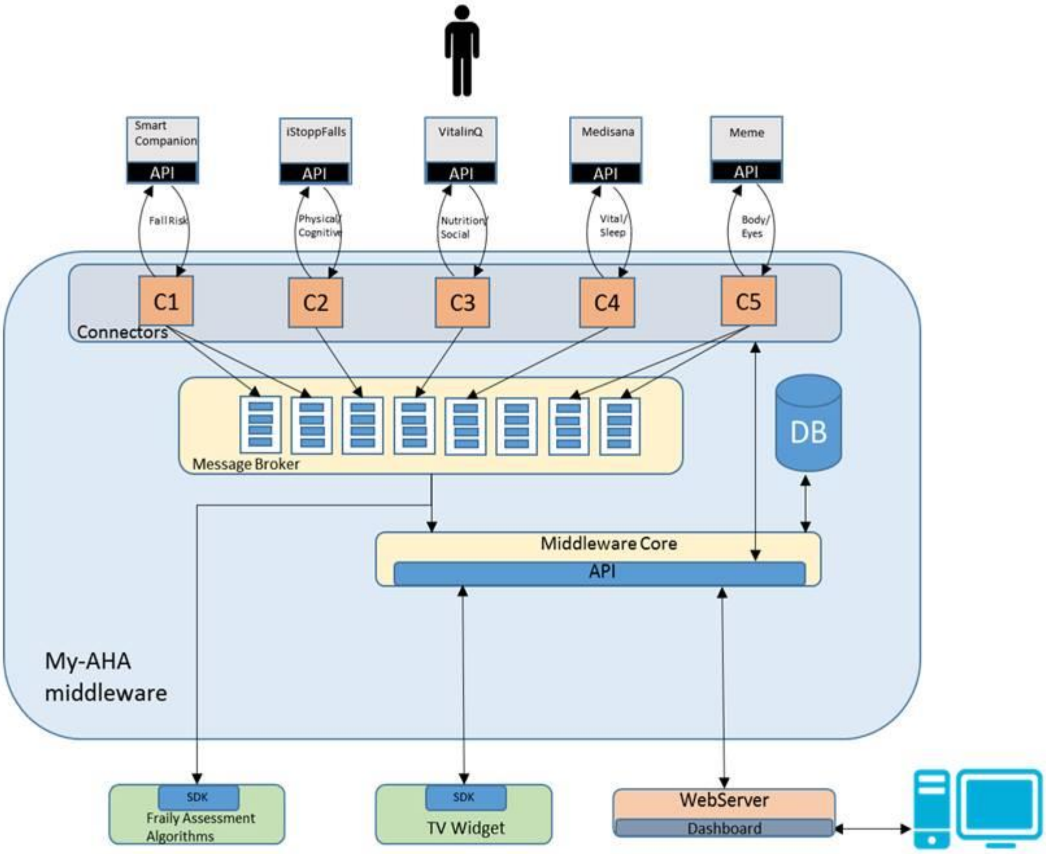


Figure 15 - Scheme of the different platforms integrated in the middleware of My-AHA. (source)

INdependent LIving support Functions for the Elderly (**IN LIFE**) is another H2020 project focusing on cognitive impairment related to early and mild dementia. IN LIFE has developed an ICT solution to support older adults with cognitive impairment who prefer to live as independently by supporting home activities – communication, health maintenance, travel, mobility and social interaction tasks – while the services are personalized to user needs (Figure 16). From an economic perspective, the IN LIFE system offers mature services tested in real-life applications in the six sites Europe-wide. Results from the trial sites show the business scenarios for care centers and indicate that the exploitation opportunities are sustainable. Use of the open Cloud platform and seamless interconnection of all the services carries with it the advantage of being low-cost to run and maintain. Furthermore, the system can be accessible anywhere and doesn't need high computing capacity (IN LIFE).

Key innovation impact is: travelling to the Cloud; bridging the Gap to the digital world and social networks for older users with cognitive impairments and Making novel, scalable and adaptive business models for the silver market, that are widely tested and of proven viability.

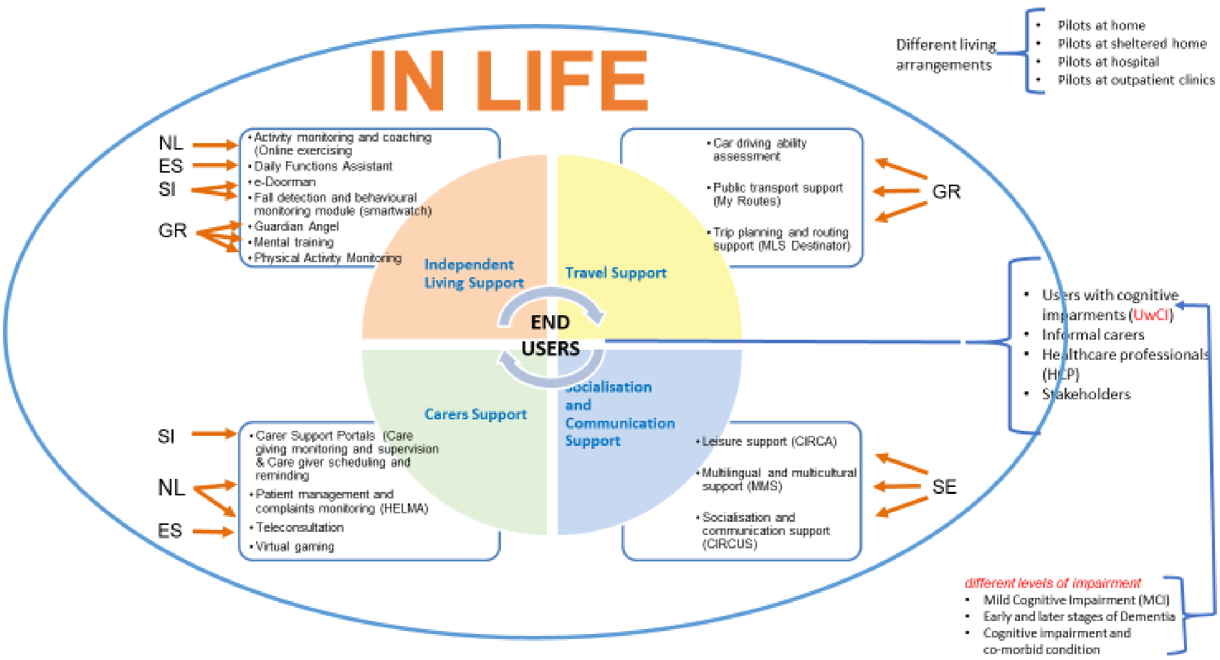


Figure 16 - IN LIFE dimensional perspective (source)

CITY4AGE is H2020 project that exemplifies efforts towards creation of age-friendly environments. The problem addressed by City4age is how to make prevention services more data-driven, effective, and sustainable. The specific focus has been put to Mild Cognitive Impairment (MCI) and Frailty. City4Age has demonstrated the usefulness of a data-driven approach, created a set of technological solutions, defined, and demonstrated some organizational solutions, providing the proof-of-concept that modern technologies can be adapted to the needs of older citizens. Its contribution can be summarized in the following:

- The data-driven computational model for MCI/Frailty is original and paves the ground for a new approach to data-drive geriatrics.
- The ability of easily accommodate various data sources into a unified data model.
- The layered interpretation of behavioural data.
- The shared repository, with millions of anonymized data made available, sharing data for research.
- The approach and technology suite supporting intervention.
- The tools for data analysis and activity recognition.

With many advantages, there are some obstacles preventing the full embrace of developed services, apart from technology penetration and economic factors. Many AAL systems rely on event detection and require hard and robust real time processing of data for providing prompt interventions while avoiding fake alarms [29]. On the other hand, long periods of observation are required for detection of changes in habits and production of new models. In these cases, offline processing can be done using a cloud computing framework [29]. Additionally, there is a need of interdisciplinary competences to cover for design, installation, acceptability, and functionality of an AAL system. Technology experts as well as HCPs, geriatricians, and psychologists, must work in interdisciplinary teams to design a robust and reliable AAL system.

The **SmartWork** project created a worker-centric AI system for work ability, sustainability, and active and healthy ageing. The system integrates unobtrusive sensing and modelling of the worker state with a sequence of innovative services for context and worker aware adaptive work support. The monitoring of the health, behaviour, cognitive and emotional status will permit the assessment of the functional and cognitive decline risk. By capturing the attitudes and abilities of the ageing worker, the system allows decision support for personalized interventions to maintain and improve the work ability, supporting the older office worker for sustainable, active, and healthy ageing [69].

The holistic approach for work ability modelling captures the attitudes and abilities of the ageing worker and enables decision support for personalized interventions for maintenance/improvement of the work ability. The evolving work requirements are translated into required abilities and capabilities, and the adaptive work environment supports the older office worker with optimized services for on-the-fly work flexibility coordination, seamless transfer of the work environment between different devices and different environments (home, office, on the move), and on-demand personalized training. The SmartWork services and modules also empower the employer with AI decision support tools for efficient task completion and work team optimization through flexible work practices. Optimization of team formation, driven by the semantic modelling of the work tasks, along with training needs prioritization at team level to identify unmet needs, allow employers to optimize tasks (e.g. needed resources), shifting focus on increased job satisfaction for increased productivity. Formal and informal carers are able to continuously monitor the overall health status and risks of the people they care for, thus providing full support to the older office worker for sustainable, active and healthy ageing [69] [70].

The modelling of work ability considers (Figure 17):

- generic user models (groups of users),
- personalised patient models,
- personalised emotion and stress models of the office worker,
- personalised cognitive models,
- contextual work tasks modelling,
- work motivation and values [69].

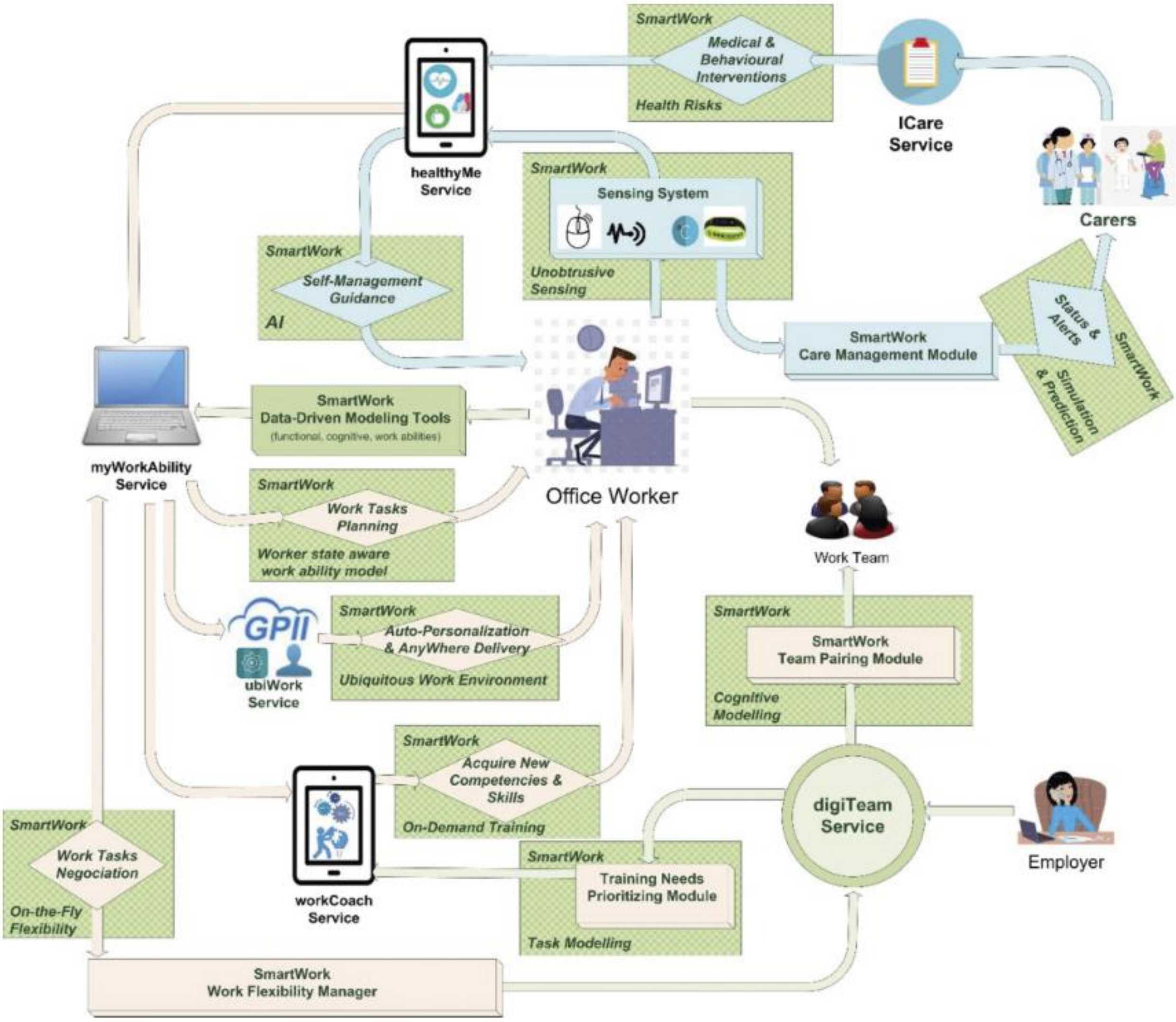
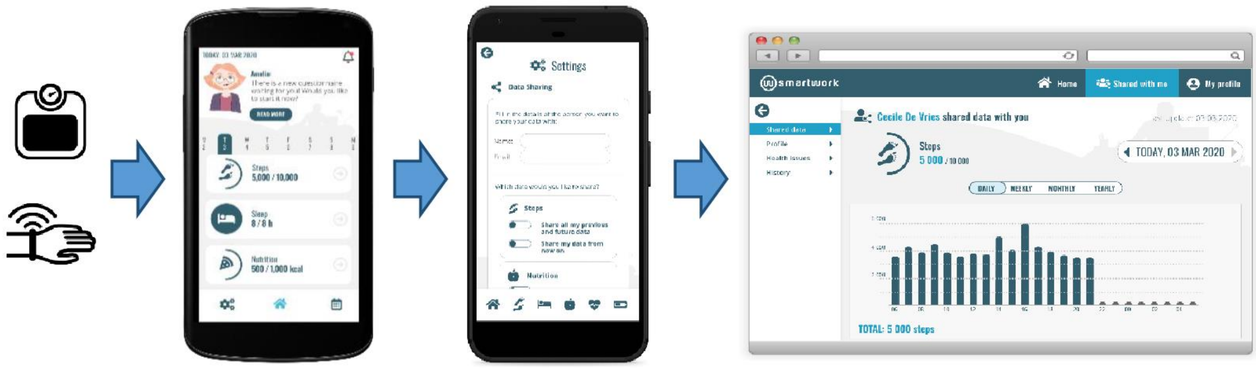


Figure 17 Generic architecture of the SmartWork suite of novel services [69]



(1) (2) (3) (4)

Figure 18 - Conceptualization of the iCare service within the SmartWork system ([source](#))

The goal of SmartWork is to make tools that are better and less likely to be misused. This may lead to innovations that would not have been thought of without having to deal with limitations and difficulties. But technology can only solve a problem so far. Even though digital health solutions could help older people stay active and healthy, society might need to change how it views older people and people with chronic conditions. A "burden" is too often used to describe an ageing population, especially on healthcare systems where costs are going up. SmartWork has a positive view of older workers, though, because they see them as valuable and experienced. So, giving older workers flexible work hours, on-demand training, and health support shouldn't be seen as an extra cost, but as a way to keep good workers for as long as possible [70].

Ethical and privacy issues: health professional in a new role

Health data come from many different sources: electronic health records, drug prescriptions, medical reports, insurance claims, IoT devices, and even social media posts. mHealth solutions rely on and exploit the data collected in the process of interaction with the user, or in the case of monitoring applications, this data is collected 24/7 and includes data from multiple sensors, sound analysis and in some cases even access to camera. This data is very sensitive personal data and can provide an insight into all segments of personal life. The regulation on use and storage of this type of data has to be very clear to potential users, as privacy is one of the major concerns related to mHealth [63]. In Europe new policies are set in place to regulate and stimulate secure and privacy preserving use of health data [71] [72]. The EU General Data Protection Regulation (GDPR) is a step towards ensuring the data privacy in terms of personal ownership, however the careful use is required at all levels starting from HCPs, public and private healthcare institutions, to companies being involved in the process or offering the services.

The mHealth involves more connectivity and communications between healthcare institutions and users/medical devices. Any device connected to the Internet is prone to be targeted for malicious purposes, at the constant the threat of privacy disruption, data theft and even financial cost [63]. The number of data breaches (detected and reported) in healthcare institutions has increased significantly in the last years [73]. However, the reasons are not primarily technical, but in largely caused by the lack of knowledge of employees in treating personal data and negligence in implementing the recommended information security practices [73]. According to the 2017 Fourth Annual Data Breach Industry Forecast, healthcare organizations will be the most targeted sector with new, sophisticated attacks emerging [63]. There is a need for solid security frameworks for m-Health to ensure security and reliability of medical devices and personal health data [74] [75]. [76]

General Data Protection Regulation (GDPR) put in practice on 25.05.2018. has unified the requirements for data protection and privacy assurance across Europe. The healthcare/monitoring systems have to adhere to privacy by design principle, which requires the incorporation of privacy protection in systems design, and n U.S. privacy law treats health data that come from different sources (EHR, or insurance claims, mHealth apps) differently depending on how they are created, and who is the custodian (who is handling the data). On the contrary, EU GDPR sets a single broadly defined regime for health data (and other data), regardless of format, way of data collection, or who is the custodian [76]. GDPR defines "data concerning health" as the category of "personal data related to the physical or mental health of a natural person, including the provision of health care services, which reveal information about his or her health status." [77].

The patient can suffer direct harm if data privacy is endangered due to the possibility of discrimination, for example if insurance house or employers get sensitive information on disease or high risk of disease, they may decide not to insure or employ the person [77]. Even more reluctant and concerned are persons whose genetic information may become available. Patients whose private health information becomes available can suffer embarrassment, paranoia, or mental pain [77].

The personal data breaches can happen not only due to insecure data storage, data handling or data transmission, but as well during data analysis. It is possible that big data analysis tools permit direct knowledge of our health by third party. People are both unaware and concerned about the uses of their health and personal data. One example comes from GEDmatch genetic database in the investigation related to the Golden State Killer [78], where for this type of data information shared about one person may reveal information about other genetic relatives—who did not consent to share the data neither they are aware that potentially revealing information has been shared.

Another issue, which is even more difficult to grasp for a non-expert is an issue raised by predictive analytics related to whether our privacy is breached when others make inferences about us (as opposed to know things about us) [79] . As ML plays an important role in digital transformation, a lot of research effort has been invested to ensure privacy preserving machine learning (ML) and avoid possibility to infer sensitive input data based on ML model decisions. In order to improve ML models more data is usually needed and organizations are encouraged to share the data, at the same time being strictly limited by privacy protecting regulations. For these reasons, privacy preserving machine learning (PPML) have been developed that allow multiple participants to individually train their ML models, and in the next step their aggregation results in a global model in a privacy-preserving manner (relying on multi-party computation or homomorphic encryption). Further efforts are needed to improve the resilience of privacy-preserving aggregation for its real-world application and provide less resource intensive implementations to suit even the use in mobile devices [80].

Identified EU projects for privacy and ethical issues in CORDIS and INNORADAR (by acronym)	
SERUMS	**SPHINX**
ASCLEPIOS	**CONCORDIA**
CUREX	FeatureCloud
PANACEA	**PROTECT**
ProTego	**SOTERIA**
DIGI-B-CUBE	

Table 6 - Privacy in healthcare related projects

In the recent years numerous EC calls relate to privacy preservation in healthcare and privacy preserving machine learning. **H2020 ASCLEPIOS** (Advanced Secure Cloud Encrypted Platform for Internationally Orchestrated Solutions in Healthcare) project worked around three identified key cybersecurity challenges:

1) many existing cybersecurity approaches fail to protect users' data against internal or external attacks;
2) healthcare data analysis should be done in secure and privacy preserving mode
3) in new medical devices some hardware components are replaced by software and HCP/users cannot attest the trustworthiness of these devices and must rely on the assurances of device vendors, operators, and maintainers.

The ASCLEPIOS aims to maximize the trust of users on cloud-based healthcare addressing the mentioned challenges with its main objectives: (1) Creating cybersecurity solutions based on Searchable Symmetric Encryption (SSE), Attribute Based Encryption (ABE) and Attribute-based Access Control (ABAC) to prevent unauthorized access to data stored in both local and remote storages. (2) Elaborating a novel solution that enables users in the Healthcare sector to run Functional Encryption (FE) enabled analytics on healthcare and medical data in a privacy-preserving and secure way. (3) Developing new attestation protocols to check trustworthiness of healthcare and medical devices.

The project has developed the ASCLEPIOS framework (Figure 19) which integrates cybersecurity services based on ABE, ABAC, SSE and FE schemes and medical device attestation. To ASCLEPIOS project implemented three near-production level demonstrators for acute stroke response, sleep disorder and antibiotics prescription analytics. The use cases are provided by the ASCLEPIOS medical partners and involve leading European hospitals.

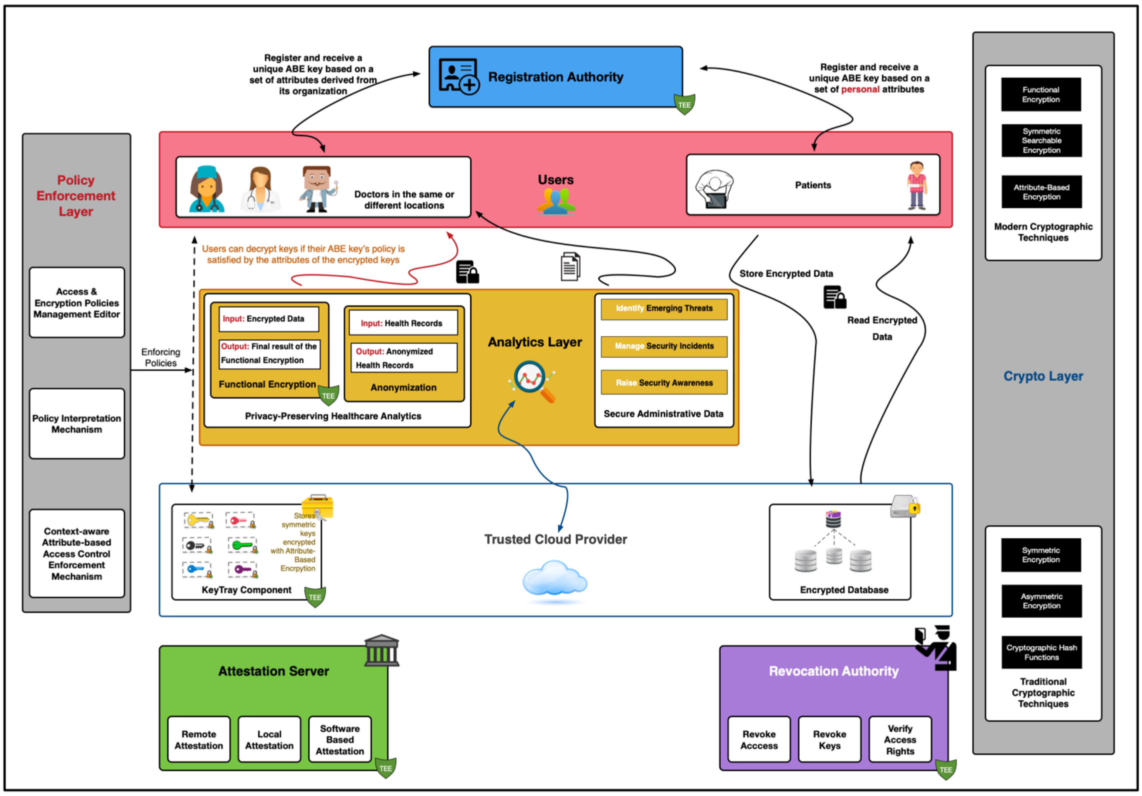


Figure 19 - ASCLEPIOS architecture (source)

H2020 CUREX (seCUre and pRivate hEalth data eXchange) proposes a risk-based cybersecurity framework taking into consideration the hospital workflows, as well as medical devices in care settings. CUREX aims to protect the health data handled by hospitals from the risks that are propagated all the way from the security gaps in their IT infrastructure by implementing a risk-based approach, performing continuous cybersecurity and privacy risk assessments based on the reported assets, vulnerabilities, and real-time detection of imminent threats. CUREX also offers optimal recommendations for cyber risk mitigations in the form of a decision support tool.

The CUREX Platform encompasses a set of tools (Figure 20) establishing trust between healthcare organizations to accommodate exchanging data in a fully GDPR-compliant manner. Working on existing distributed ledger and health technological artifacts, CUREX ensures the accountability and auditability of all transactions between hospitals and care centers. Finally, to address the human factor, it improves the cyber hygiene culture among personnel through identifying employee group-specific gaps and needs with regard to raising data privacy awareness.

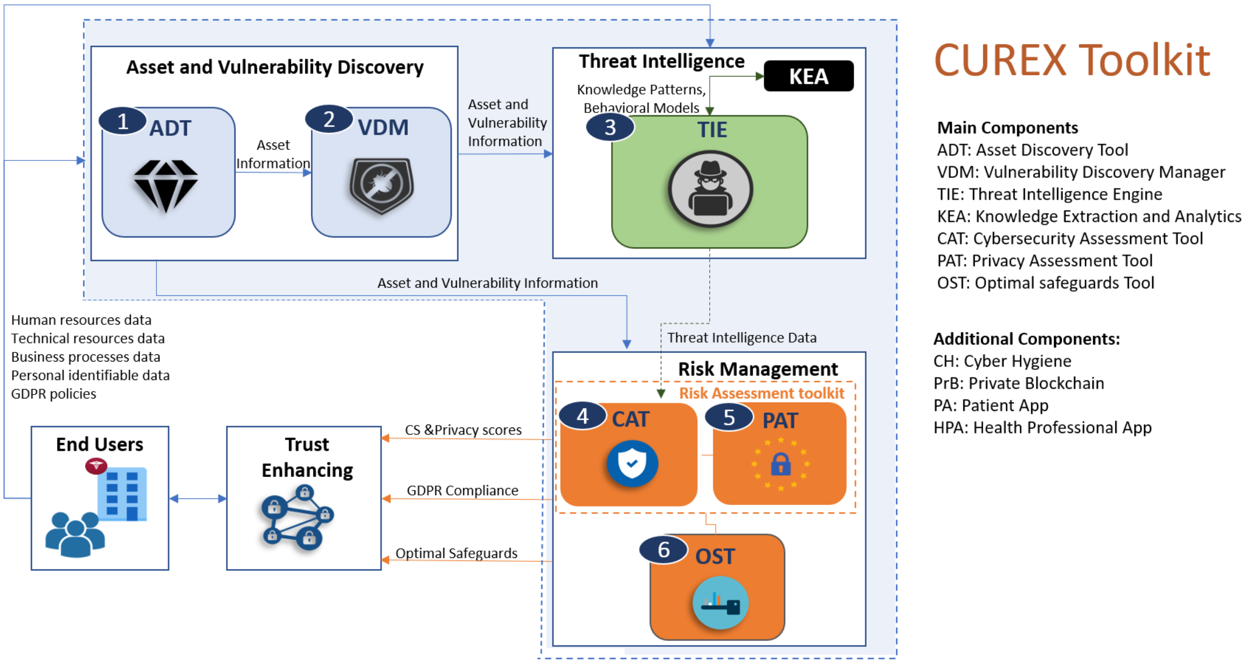


Figure 20 - CUREX Toolkit (source)

Efficiency and efficacy

Digital health transformation and paradigm of eHealth and connected health empowers the patients and place them in the center of their own care. There are multiple ways in which digital health offers improvement in efficiency and efficacy of healthcare [45] [66] [40] [56] [63] [64]:

1) **More efficient patient data collection and exchange** - the digital data storage and possibility of secure data exchange between primary care, specialist centers and tertiary care allows for a more efficient patient treatment, with all patient history and information easily at hand.

2) **Opportunities of AI based predictive analytics -** the immense collection of data opens un unprecedented opportunity for the use of AI and ML to exploit and uncover new knowledge. Electronic Health Records (EHR) permits structured data acquisition which can be easily extracted from health information systems. Using ML algorithms to learn from patient data results in improved tools for support in diagnostic. Moreover, relating patient history and other comorbidities, new association rules can be learned out of big amounts of data.

3) **Personalized medicine - Multiscale perspective on health and multiscale data analysis** Incorporating patient data from multiple scales, from genetic to phenotype, offers a full picture of human health and in the future opens the promise to find mechanism of disease development and possible ways

to reverse the process and offer an efficient treatment. Patient specific disease signatures can be used to shape the treatment and recovery process more efficiently and cost effectively.

4) **Mhealth and pervasive monitoring** – mobile applications connected with embedded sensors or wireless sensor networks can offer a continuous monitoring of physiological signals and critical health variables. This can lead to improving the qol and cost efficiency for the care of older people, providing for the timely and prompt actions. Moreover, at least a regular periodic monitoring of vital variables can potentially facilitate an early diagnosis by identification of a disturbed health status.
5) **Mhealth apps and patient education –** education based applications can help persons learn more about disease, signs, and symptoms, thus in a long term preventing the severe development of disease and enabling timely specialist appointments, which in turn leads to more efficient treatment and less associated cost.
6) **Broaden availability of services through ease of access, reducing inequalities –** spectra of services offered introducing mhealth and ehealth, the need for infrastructure investment can be reduced by offering remote access to deficient expert services or at least more efficient patient triage. Remotely located persons can access the services, get informed and interviewed and in case of real need, make an appointment with specialist, reducing time needed to reach this level of care.
7) **Reduce human resource burden on healthcare system** – patient driven care contributes not only to timely and more efficient diagnoses and treatment, but as well reduces the burden from HCP and the whole system, where the in person appointments are made after an initial triage and by priority.

All aforementioned items (which do not represent an exhaustive list) contribute in long term to a more efficient healthcare system, both from the user perspective and within system perspective. Though most economic evaluations are done on relatively short-term (one or two years), there are indications that, especially in rural areas, using eHealth tools are cost-beneficial compared to conventional healthcare services, either by decreasing administration costs, automated screening and increase of work efficiency [81]. The staff reduction is not an immediate result, neither highest in priority. eHealth and mHealth require digital skills to get acquainted and efficient with these tools. The technology has to be fully integrated into hospitals/points of care before any reduction of personnel can be achieved, if needed.

Within Low and Middle Income Countries (LMICs) the adoption of smartphones and an overall technology supported progress has coincided with the growth of socially mobile middle-class populations. In those countries sluggish healthcare systems cannot efficiently provide novel and cost-effective services for the growing middle classes. This contributes to flourishing of the parallel private hospitals and services, which are still out of financial reach of many people. Smartphone-based medical consultations, ePrescription, and appointment bookings have emerged as a possible solution to reach the desired services, yet often with a great delay. In LIMIC current health expenditures imply that investing in e-Health services and transformation of health system in a long run provides multiple values, but it is a cohesive effort of business, medicine, technology, and related industry [82].

Identified EU projects for efficiency and efficacy in CORDIS and INNORADAR (by acronym)	
FUTUREID	SIGUEMED
MAESTRA	DigitalHealthEurope
FERARI	InteropEHRate
ANCIEN	4-D nanoSCOPE
SOPHIE	MyGoalMEDAL
WE-CARE	**Medical Express**
FUTURID	**ReHaptix**
TICD NOVEL	**Sano**
COURAGE IN EUROPE	**ConcePTION**
AGE-FRIENDLY	**IMPACT EdTech**
VALUE-HEALTH	**X-eHealth**
ELECTOR	WideHealth
ROBOT-ERA	**REALMENT**
INTEGRATE	**XpanDH**
PHARMA LEDGER	GenoMed4ALL
iGame	**SHIFT-HUB**
UNICOM	**ODIN**
DIAIoT	**CHAIMELEON**
EASY-Diabetes	

Table 7 - Efficiency and efficacy related projects

The research projects related to implementation of eHealth systems focus their attention on development of secure and cost-effective platforms.

PharmaLedger is a Public Private Partnership (PPP) Project, backed by a consortium of 29 public and private entities, including global pharmaceutical companies, universities, technical partners, research organizations, hospitals, and patients` organizations. The project aim is to create an agile and secure **blockchain-enabled platform** that supports, on the top of it, a set of decentralized and trustless healthcare solutions by nature: a) exchange data in a way that, data and processes compliant with current standards of the healthcare sector and legal and ethical framework (data and processes are privacy-enabled by design), and b) allow security, trust and provenance of data and information, by linking data and processes together through the PharmaLedger platform services allowing for secure, permissioned, auditable, and patient-mediated exchange of data environment.

PharmaLedger provides a 4 layer architecture (Figure 21); the three layers at the bottom ensure the data self-sovereignty through the Open Data Sharing Units (OpenDSU) approach, while the top and fourth layer enables and integrates the solutions and applications being developed for the use cases (Figure 22). An added value is created for all stakeholders through an interoperable platform, that manage digitized as well as accessible immutable and traceable data, and combines integrity, traceability, and non-repudiation as the benefits of Blockchain while preserving confidentiality and data privacy for the data owners.

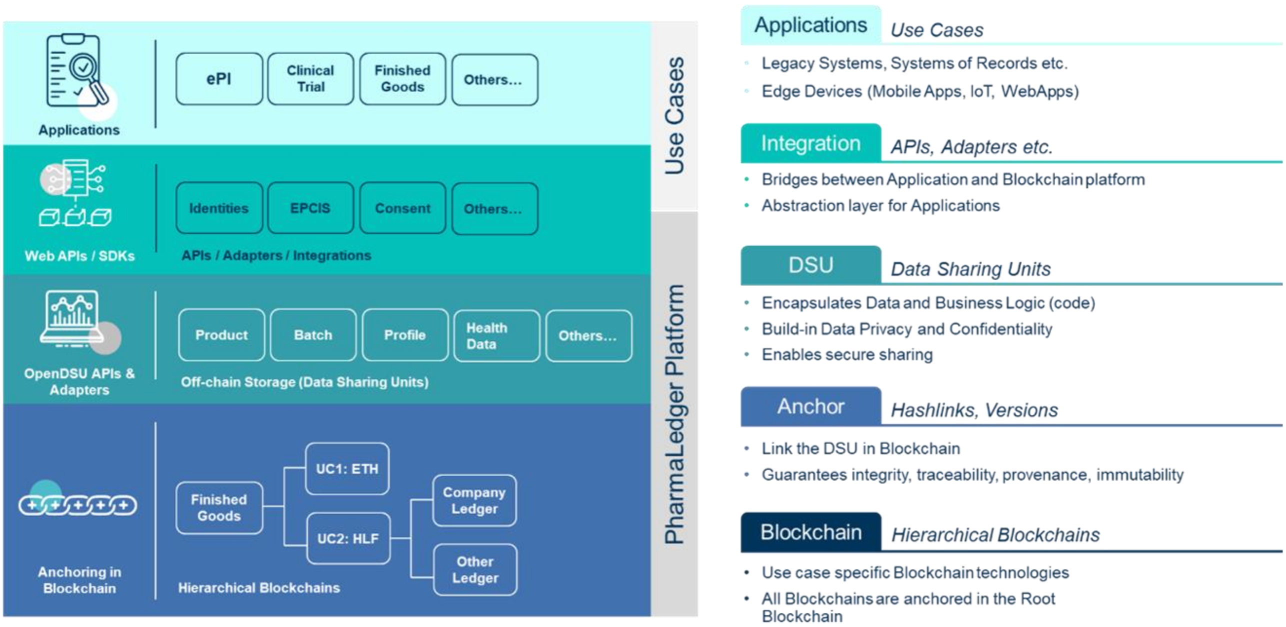


Figure 21 - Pharma Ledger architecture

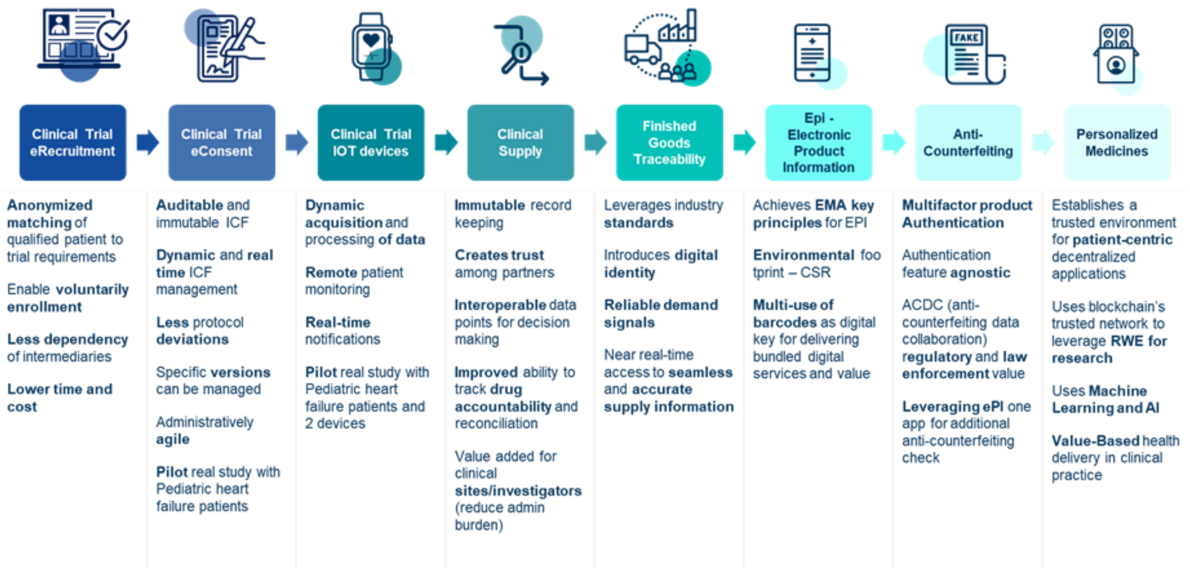


Figure 22 - PharmaLedger Use Cases in healthcare value chain

Technological advances such as artificial intelligence and big data are set to transform healthcare in a positive way. These smart health technologies usually employ sensors to obtain information that is transmitted and processed using cloud computing. However, their uptake is often impeded by poor awareness and literacy.

To address these limitations, the EU-funded **SHIFT-HUB** project (*Smart Health Innovation & Future Technologies Hub*) proposes to establish a patient-driven approach for creating and adopting smart health solutions. The project will set up a network of healthcare organisations that will implement selected smart health applications after they have been tested by patients and online users. SHIFT-HUB aims to establish a pan-European Smart Health Innovation Hub bringing together a rich network of multidisciplinary stakeholders across the dimensions of the quadruple helix, with the mission to facilitate the development, ensure the promotion and foster the uptake of Smart Health technologies and services. SHIFT-HUB will develop and test with the community a complete service offer, integrating networking and matchmaking, identification of partners and support for procurement, guidance for access to funding, research infrastructures and scientific expertise (SHIFT-HUB)

In conclusion, by leveraging technology thoughtfully, we can create environments that not only support the population in practical ways but also enhance their overall health, wellbeing, and sense of community. Balancing efficiency with a focus on personalized, user-centric approaches is key to realizing the full potential of digital innovations in promoting Smart Healthy Age-Friendly Environments. Efforts should focus on technological inclusivity, privacy safeguards, cost-effectiveness, cultural considerations, regulatory frameworks, and community engagement to ensure that SHAFE initiatives not only leverage the full potential of digital innovations but also genuinely enhance the health and wellbeing of all people.

5. KNOWLEDGE BASE ONLINE REFERENCE TOOL

5.1 Overview

Along with the desk search performed and detailed in the previous chapters, the work within the WG3 of the Action encompassed the development of an online knowledge base, that is, a repository of knowledge about salient relevant data that enables users to explore some digital innovation examples related to SHAFE. The knowledge base provides data domains that relate to the data sources, aimed to be versatile in the way it can be used. For the preliminary organisation and collection of knowledge, there was a clear option of valuing this aspect of practicality in detriment of strict and formal queries and keywords.

The searchable online tool, available at https://www.net4age.eu/analysis-responses, was thus developed to enable a user to search through the entries using either, or a combination of the following fields:

1. SHAFE Ontology Terms
2. Category
3. Keywords

Resulting matches to the search terms above are displayed, allowing the user to view the in-depth analysis of the entry.

5.2 Methodology applied to collate the Knowledge Base Entries

In what concerns the methods applied to develop this Knowledge Base, the Action members were invited to submit entries which have relevance in the field of SHAFE to an online file. During the initial preparatory discussions, it was decided that entries were to be categorised under either of the following categories:

1. Best Practices
2. Case Studies
3. Data Sets
4. Development
5. Projects
6. Standards
7. Taxonomies
8. User Experience
9. Other

This exercise resulted in an initial list of 97 potential activities for inclusion in the Knowledge Base.

The entry analysis, classification and process were performed by WG3 members, online and in WG meetings. During the Working Group meeting in Hamburg in 2022, a preliminary analysis of the initial Knowledge Base entries was performed and the methodologies for their analysis were discussed in further detail. It was decided that the main entry classification methodology was to be based on the SHAFE Ontology, which had recently been completed as part of WG5 activities. WG3 members were subdivided into a number of separate task groups, each responsible for the analysis of entries within a specific category as described above. The analysis continued during the following meeting in Treviso (2023), with intense activity within task groups in order to progress with the cataloguing and analysis of these entries. The process was approximately 80% concluded and finalised at the Hague in May 2023, thus concluding the Knowledge Base.

5.3 Integration of the SHAFE Ontology

The SHAFE Semantic Ontology Model (SOME) was developed separately in WG5 *Reference Framework* of the Action, with the aim to investigate the use of a general and formal semantic based ontology model to represent knowledge related to Smart Healthy Age-friendly Environments (SHAFE) using linguistic properties.

This model is implemented using a semantic based approach by means of knowledge graph (KR) and an *ad hoc* language, the Ontology Web Language (OWL). The designed knowledge graph has a natural implementation by means of NoSQL Graph data base management systems (DBMS) in the BigData realm.

During the Knowledge Base entry analysis process, discussed below, each entry was tagged using one or more terms from the ontology, thus providing a first practical application of the ontology. In addition, during this analysis process, additional terms were identified for potential inclusion in the ontology, providing an incremental feedback loop to the ontology itself.

5.4 Analysis Methodology

The analysis outcome per knowledge base entry was documented through an online form, requiring the following information to be provided:

General Introductory Project/Activity Information

Title	Project/Activity Title
	Text
Category/Type	Best category fit for the Project/Activity
	Drop Down
Description	Detailed Description of the Project/Activity
	Text
Sources	Information Sources (documents, URLs etc) referenced for analysis

	Text
Keywords	Most relevant keywords for Project/Activity
	Text
	Detailed Project/Activity Information
Overview	A detailed description of the initiative
	Text
Objectives	A description of the objectives of the initiative
	Text
Ontology Terms	Selection of relevant Ontology terms for the initiative
	Multiple selectable check boxes
Additional Terms	If applicable, suggested terms relevant to this activity that are not available from the NET4Age Ontology Terms
	Text
Strengths	Initiative Strengths, Innovation, and relation to State-of-the-Art
	Text
Shortcomings	If applicable, a description of identified initiative shortcomings
	Text
Relevance	A description of the initiative relevance to NET4Age
	Text
Relevance Ranking	Likert Scale (1-5) ranking of relevance
	Radio Buttons
Overall Quality	Likert Scale (1-5) ranking of initiative quality
	Radio Buttons
Overall Opinion	Concluding remarks on the initiative
	Text
Overlap	If applicable, a description / links to other similar/overlapping initiatives

Text

All entries were collected in a database and subsequently normalised, cross-checked and imported/published into the online tool.

5.5 WG1 Data Aggregation

WG1 followed a similar methodological approach for the collection and analysis of initiatives related specifically to User Experience, resulting in the inclusion of an additional 94 entries incorporated in the search tool under the User Experience category.

6. RECOMMENDATIONS FOR THE MODULE ON DIGITAL INNOVATIONS

The Module on digital innovations and implementation in Smart Healthy Age-Friendly Environments should integrate the inputs and recommendations from diverse stakeholders. This collaborative approach aims to create a comprehensive and adaptive framework that maximizes the positive impact of digital technologies on the health, wellbeing, and quality of life of the whole population.

IDENTIFIED STAKEHOLDERS	INPUTS	RECOMMENDATIONS
Industry leaders	**Market trends and innovations:** Stay updated on emerging technologies and market trends in digital health and age-friendly solutions. **Best practices:** Share insights on successful implementations and industry best practices for integrating digital innovations in SHAFE.	**Collaborative partnerships:** Foster collaborations between industry leaders, technology developers, and healthcare providers to create integrated and interoperable solutions. **Investment in R&D:** Allocate resources for R&D to continuously improve and advance digital solutions tailored for SHAFE.
Policymakers	**Regulatory frameworks:** Understand the current regulatory landscape and policy frameworks related to digital health, ensuring alignment with evolving technologies. **Public health insights:** Consider public health insights and epidemiological data to inform policies that address the specific healthcare needs of ageing populations.	**Agile policy development:** Establish agile policy development processes that can adapt to the dynamic nature of digital innovations and address gaps in regulatory frameworks. **Incentives for adoption:** Implement incentives for organizations and healthcare providers to adopt and integrate digital health solutions, aligning with policy objectives for improved SHAFE.
Researchers	**Evidence-based research:** Contribute evidence-based research on the efficacy and impact of digital	**Longitudinal studies:** Support longitudinal studies to track the long-term effects of

	innovations in enhancing the health and wellbeing of ageing populations. **User experience studies:** Conduct studies on the user experience of older adults with digital technologies to inform user-centric design principles.	digital innovations on the health outcomes and quality of life of ageing population. **Knowledge dissemination:** Disseminate research findings through accessible channels to inform policymakers, healthcare providers, and technology developers.
Technology users	**User feedback:** Provide insights and feedback on the usability, accessibility, and effectiveness of digital health tools from the perspective of people of all ages and their caregivers if adequate. **User preferences:** Communicate preferences and needs regarding digital innovations, ensuring that technology aligns with the lifestyles and values of the people in different age groups.	**User education programs:** Advocate for user education programs to enhance digital literacy, fostering a sense of empowerment and confidence in using technology. **Participation in design:** Encourage the active participation of people of all ages, including the ageing population in the design and testing phases of digital solutions to ensure user-centricity.
Healthcare providers	**Clinical insights:** Share clinical insights on the integration of digital health tools into existing healthcare workflows, including challenges and successes. **Patient outcomes:** Contribute data on patient outcomes and experiences related to the use of digital innovations, informing evidence-based practices.	**Continuous training:** Provide ongoing training to enhance digital literacy and proficiency in utilizing digital health tools for improved patient care. **Interdisciplinary collaboration:** Foster collaboration between healthcare providers, technologists, and researchers to develop comprehensive and patient-centered digital health strategies.

Community organizations	**Community needs assessment:** Conduct needs assessments within the community to identify specific challenges and opportunities in digital health adoption among people of different ages. **Community engagement strategies:** Share successful strategies that promote awareness, education, and inclusivity in the adoption of digital innovations.	**Local implementation initiatives:** Initiate local implementation initiatives that tailor digital solutions and innovations to the unique cultural and social contexts of different communities. **Resource mobilization:** Advocate for resources to support community-based digital health programs, ensuring equitable access for all, especially for people in vulnerable situations.
Caregivers (and family members)	**Caregiver experiences:** Share experiences and insights on the role of digital innovations and solutions in caregiving, including challenges faced and benefits observed. **Family dynamics:** Provide perspectives on how digital technologies can enhance family support networks and improve communication and coordination in caregiving.	**Caregiver support programs:** Advocate for programs that provide caregivers with training and resources to effectively leverage digital innovations and solutions in caregiving. **Communication platforms:** Encourage the development of communication platforms that facilitate collaboration among family members and caregivers, enhancing overall care coordination.
Technology developers	**User-centric design principles:** Gather insights on user preferences and experiences to inform the design of digital health solutions that prioritize usability and accessibility. **Technical challenges:** Understand technical challenges faced during the development and implementation of	**Collaborative development:** Engage in collaborative development processes with end-users, healthcare providers, and researchers to ensure that technology solutions meet the evolving needs of SHAFE. **Continuous improvement:** Establish feedback loops for continuous

	digital innovations and solutions, including interoperability and security issues**.**	improvement based on user feedback, technological advancements, and changing healthcare landscapes.
Advocacy groups	**Policy advocacy**: Advocate for policies that support the adoption and integration of digital innovations in SHAFE, addressing regulatory barriers and promoting incentives. **Public awareness campaigns**: Contribute to public awareness campaigns that highlight the benefits of digital health tools and promote inclusivity in adoption.	**Collaborative advocacy**: Collaborate with other advocacy groups, stakeholders, and policymakers to amplify the collective voice in support of digital innovations for people of different ages, especially the more vulnerable. **Leveraging data for advocacy**: Utilize data on the impact of digital innovations to advocate for evidence-based policies that prioritize the health and wellbeing of the population.

Table 8 - Recommendations for the Module on digital innovations and implementation

The future Module on digital innovations and implementation of SHAFE solutions can follow the proposed structure below, considering the inputs and recommendations for identified stakeholders within this report.

Introduction

- Overview of the significance of digital innovations in promoting wellbeing and quality of life for people of different ages, especially the more vulnerable.
- Recognition of diverse stakeholders and their pivotal roles in the implementation process.

Policy frameworks and regulatory considerations

- Examination of the current policy landscape related to digital health in SHAFE.
- Recommendations for policymakers to establish adaptive policies supporting innovation while safeguarding ethical standards and patient rights.

Stakeholder engagement and collaboration

- Identification of key stakeholders, including industry leaders, policymakers, researchers, technology users, healthcare providers, community organizations, caregivers, technology developers and advocacy groups.
- Strategies for fostering collaboration, communication, and collective efforts among stakeholders.

Recommendations for stakeholders

- Follow the proposed framework and improve it.

Framework for implementation

- Development of an implementation roadmap with phased milestones, key performance indicators (KPIs) and timelines.
- Strategies for monitoring and evaluation to assess the impact of digital innovations on health outcomes and overall wellbeing.

Conclusion

- Recapitulation of the collaborative and inclusive approach required for successful digital innovation and implementation of SHAFE solutions.
- Emphasis on the potential for positive transformations in the health, wellbeing, and quality of life for people of different ages, especially the more vulnerable.

This module should be a comprehensive guide, providing actionable recommendations for diverse stakeholders to contribute to the successful integration of digital innovations and implementation of SHAFE solutions.

The successful implementation of digital innovations and implementation of SHAFE solutions requires a collaborative and adaptive framework involving diverse stakeholders. Industry leaders should stay informed about market trends, policymakers must establish agile policies, and researchers should contribute evidence-based insights. Technology users, including all people and if applicable their caregivers, play a crucial role by providing feedback and participating in design processes. Healthcare providers need continuous training, while community organizations and advocacy groups contribute to localized initiatives and policy advocacy. Finally, technology developers should prioritize user-centric design and continuous improvement. This collective effort aims to create an inclusive, user-friendly, and effective digital ecosystem that enhances the health, wellbeing, and quality of life through SHAFE implementation.

7. CONCLUSIONS

Digital innovations in the context of Smart Healthy Age-Friendly Environments (SHAFE) can have a transformative impact on the **wellbeing and quality of life** for people of all ages and characteristics.

By fostering social connectivity, promoting mental health, and providing personalized experiences, these innovations may contribute to a more fulfilling and engaging life. The integration of technology aligns with the principles of active and healthy living, empowering individuals to maintain a sense of purpose, social connectedness, and overall wellbeing. However, challenges such as the digital divide and technological anxiety need to be addressed to ensure inclusivity and widespread access, ensuring that the benefits of digital wellbeing interventions are realized by all. Challenges include addressing disparities in technology access, tailoring solutions to diverse needs, and ensuring that the digital tools enhance, rather than replace, human interactions. Continuous efforts to bridge the digital divide and promote user-friendly technologies will be crucial in maximizing the positive impact on the wellbeing and quality of life of the population.

The transformative impact of digital innovations on **healthcare delivery and prevention** is evident through remote monitoring, telehealth services, and data-driven preventive measures. Digital innovations play a pivotal role in revolutionizing healthcare delivery and prevention strategies within SHAFE initiatives. The shift towards proactive and preventive care, facilitated by digital technologies, enhances the overall effectiveness of healthcare systems, allowing for early detection and management of health issues. Overcoming challenges related to interoperability, data security, and regulatory compliance is essential for seamless integration. A balanced approach that combines advanced technology with a human touch is necessary to ensure personalized, patient-centric care. Emphasizing data governance and standardization will be pivotal to maintaining the integrity of healthcare delivery systems.

The integration of digital innovations promotes **independent living and the creation of age-friendly environments**. Smart home technologies, assistive devices, and ambient intelligence contribute to a supportive ecosystem that enables people to age in place comfortably. These innovations not only enhance safety and security but also provide adaptive solutions, fostering autonomy and a sense of control over one's living environment. The challenge lies in making these technologies affordable and accessible to a diverse population. Additionally, addressing concerns about data privacy and the ethical use of monitoring technologies is crucial for building trust. Collaborative efforts between technology developers, policymakers, and community stakeholders are necessary to create universally accessible age-friendly environments.

As **healthcare professionals** assume **new roles** in managing digital innovations within SHAFE, ethical considerations and privacy issues become paramount. Balancing the benefits of technology with ethical standards is essential to ensure patient confidentiality, informed consent, and transparent data practices.

Healthcare professionals must navigate these challenges to uphold the trust of people and maintain the highest standards of care in the digital age. Addressing challenges related to informed consent, ethical data use, and ongoing education is critical to maintaining trust and upholding the highest standards of care. Professional development programs must equip healthcare providers with the necessary digital literacy and ethical guidelines to navigate the evolving landscape.

Efficiency and efficacy are critical factors in the success of SHAFE initiatives leveraging digital innovations. The streamlined delivery of healthcare services, optimized resource allocation, and seamless interoperability of technologies contribute to the overall efficiency of these programs. Concurrently, the effectiveness of digital solutions in addressing the unique needs of people enhances the efficacy of SHAFE, ensuring that the outcomes align with the intended goals of improving health, wellbeing, and overall quality of life. However, challenges such as resistance to change and the need for technology literacy highlight the importance of comprehensive strategies for implementation. System-wide collaboration, comprehensive training programs, and effective change management strategies are essential to overcoming these challenges. Furthermore, continuously assessment of the efficacy of digital solutions through data-driven metrics and user feedback ensures that technology aligns with the evolving needs of old people and healthcare providers.

In conclusion, the integration of digital innovations in SHAFE represents a paradigm shift in how we approach an active and healthier life course. By prioritizing wellbeing, embracing preventive strategies, enabling independent living, addressing ethical considerations, and optimizing efficiency, digital innovations emerge as powerful tools to create environments that not only support the population but also enhance the overall life experience.

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ChatGPT, as an AI tool, was used to improve the recommendation framework based on identified stakeholders, which is further developed, and to identify additional well-being challenges, besides socio-economic previously identified.

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