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# Towards Internet of Things Supported Active Ageing and Home-Care

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**Abstract:** Population-ageing, due to rising life expectancy, has been observed in most Western and the developed Asian-Pacific countries. It is important to ensure for the ageing population, the necessary technical-background, the medical-managerial environment and the social-economic conditions, ensuring a better perspective for their "third age". WHO summarizes this perspective in three cardinal aspects of life i.e. Health-Participation-Security. An important factor to ensure these aspects of "successfully ageing" is the existence of a social network, supporting healthy and active seniors to prevent themselves from illness and accidents and to help the ones suffering from chronic diseases, physical disabilities or mental impairment, to sustain stable or even improve their conditions. The purpose of this paper is to review the advances, of the already ITU-FG-M2M-SL-2014 defined: "Requirements and architectural framework" so called "Internet of Things" (IoT), towards active ageing and ICT-supported Home-care, as reflected on relevant Industrial Property (IP) Documents, published during the last five years. Further, it is attempted to inspect an emerging, correlation, between "successfully ageing", industrial and economic progress and social welfare, for the ageing populations of the "traditional" and the emerging "new" industrial countries and the perspectives of their fruitful cooperation to face these challenges.

**Keywords:** Ageing, Internet of Things, Home-Care

## 1. The World Population-Ageing

Over the past 200 years, life expectancy at birth has doubled from around 40 years to over 80 years in countries in Europe, in Japan etc. In some countries such as France, where 250 years ago life expectancy at birth was slightly over 25 years, life expectancy has increased by almost 55 years [1]. At the beginning of the 20$^{th}$ Century, the life expectancy at birth of women in Germany was 48 years, and that of men was 45 years, while currently it is 82 and 77 years, respectively. This achievement was initially due to overcoming infant and childhood mortality, but during the last decades, it has mainly been occurring at later stages in life. Life expectancy is now rising markedly among older adults in particular. The percentage of the elderly within the population of Europe tends to doubling over the next decades.

The impressive increase in life expectancy that has been observed since the middle of the 19$^{th}$ Century and the high, still growing, mean population age constitute a "Novum" in human history. This demographic change is not limited to Europe, but reflects rather a global trend. By the middle of the 21$^{st}$ Century, it is likely to be more people over 50 years, than below 15 years, upon the globe [2]. Although these trends have been well documented, there remains much disagreement about their meaning and the question is whether these trends predict future developments in life expectancy. Although more people are reaching very old age in Germany, with better physical and cognitive functioning, the trends in labor market participation have pointed in the opposite direction. For instance, about 25% of the 60-65 year old in Germany, are still employed, since only a few percent among the over 65-year old citizens, are still professionally active, although the official retirement age was raised to 67 years, for the younger generations [3]. The population is growing older and declining and cardinal questions are raised, such as whether the achievements of the welfare state might be maintained and even further developed and consequently, if this situation might constitute a threat to the productivity of the country. Leading German research Institutes, argue that living standards will not be in jeopardy,

if the number of employees and their productivity can be raised, by activating reserves on the German labor market among the employed people over 55-years old, among women, and migrants, combined with targeted investment in continuous education and with optimized work organization [4]. Similarly, in Austria in the productivity trends analysis, a negative effect appears, for the share of industrial workers, under 29 years. However, no significant effect of the share of 50 years and older employees has been found [5]-[7].

The Guiding Principles on Active Ageing and Solidarity between Generations (Council of the European Union, 2012) reaffirmed that active ageing need to be promoted in the three domains of *employment, participation in society and independent living*. Thus, these principles have served in the present project, as a roadmap and the available statistical data (UNECE-AAI Results as revised on 10th March 2013) [8], [9]

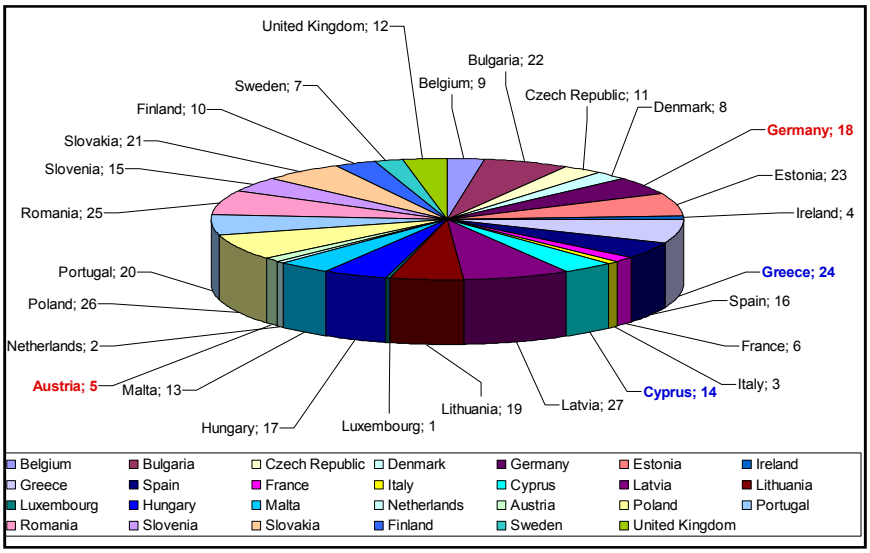


***Figure 1.*** *Overall participation in societal activities for male population in the 27 Member-States of the EU.*

concerning the EU-countries, have been extracted, used and processed, as far as Active Ageing is concerned. The Mean Values concerning all participation-forms of ageing population (55-74) for the EU are:

- Voluntary Activities (VA) 14.9 %.
- Care to children and grandchildren (CC) 32.4%.
- Care to elder adults (EC) 12.8 %.
- Political participation (PA) 12.1%.

We have compared also selected "couples" of European Countries, for instance Germany and Austria, representing the "North" versus Greece and Cyprus, representing the "South" in a Case-Study concerning Active Ageing of the corresponding populations. The choice of these "couples" was based on the fact that the selected countries, in both couples, are sharing common language, civilization, tradition and mentality, expected to lead to similar attitudes and expectations, for the meaning and the content of an "Active Ageing".

Further, the Germany-Austria couple includes two leading countries of the EU in Technology, Economic Prosperity and Competitiveness, since Greece and Cyprus are two Mediterranean countries, facing both for years a serious economic crisis. Some indicative results are summarized below.

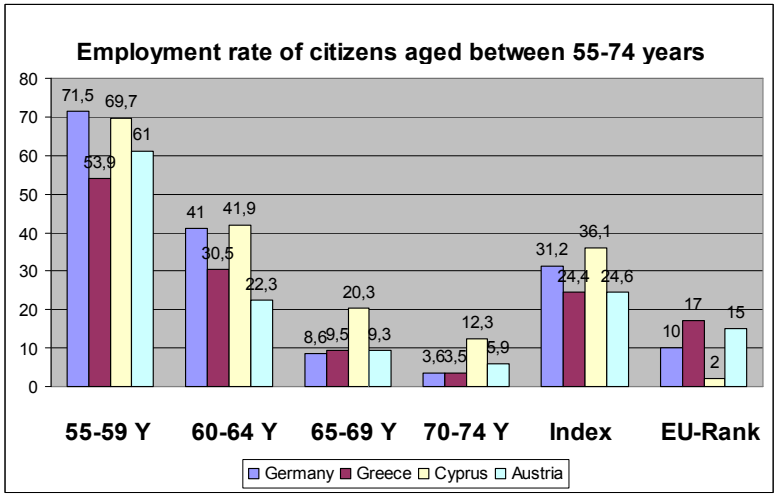


***Figure 2.*** *An indicative grouping of the Employment rate of citizens aged between 55-74 for the selected countries.*

Germany is still the "Locomotive" of the European train, in scientific-technical innovation (rank 5 worldwide), industrial potential and social initiatives, including Ageing. However, the enormous effort to incorporate the former DDR and to include the East-European countries in the EU, allows for rank-9 in total AA and leading position in 4/18 of its components.

Austria (rank-10) is leading in 10/18 components; Austrians are working fewer years than Germans and have remarkable rating, almost in anything.

Cyprus (rank 7) is the big surprise leading in 4/18 of the AA-components, although they have to pay also for health and social security of the population, living in the occupied 40% of the country. Finally, Cypriots work longer than all other Europeans, second only to Swedish.

Greece (rank-24) is not leading in any AA-component, although, for most of them, the corresponding data are rather close to the ones of the other three countries. The rank-24 is rather misleading, because Greeks are able to balance their mismanaged state-economy, with a unique "family socialism"; parents/grand-parents are strongly supporting the ill-paid or unemployed (~27%) younger generations.

It becomes obvious even from the small portion of processed relevant data presented above that the Ageing procedure is a multifarious and multifaceted procedure, especially if we address this problem, on a global scale. However, it is common place to say that the developed during the last 20 years medical-managerial methods and the accumulated "know-how" concerning the biomedical-technological aspects of Ageing, have generously contributed to the prolonging of life expectancy at birth, as we shall see in the following parts of this paper.

The purpose of this paper is to review the advances, of the already ITU-FG-M2M-SL-2014 defined: "Requirements and architectural framework" so called "Internet of Things" (IoT), towards active ageing and ICT-supported Home-care, as reflected on relevant Industrial Property (IP) Documents, published during the last five years.

Further, it is attempted to inspect an emerging correlation, between "successfully ageing", industrial and economic progress and social welfare, for the ageing populations of the "traditional" and the emerging "new" industrial countries and the perspectives of their fruitful cooperation to face these challenges.

## 2. Home-Based Services and Preventive Health Self-Monitoring

The increasing percentage of the elderly, within the population of the Western and the developed Asian-Pacific countries, has focused ICT and Assistive Technologies R&D on the development of Ambient Assisted Living (AAL) conditions. Presently, there are efforts to expand the home-based services, to include the:

- Integration and miniaturization of health self-monitoring.
- All available communication and computing systems.

That means a fast transition towards an extended home-based and mobile WiFi-enabled IP-hub, providing for health-optimization, by preventive health self-monitoring, as for example, home-based in vitro Diagnostics, optical inspection and documentation of skin alterations etc.

After more than 15 years of experience concerning medical-managerial and technological aspects of Ageing, it became clear to us that there is a high degree of heterogeneity, within the ageing population.

This could be roughly classified in four main groups:

- Healthy and active seniors.
- Elderly people with chronic diseases.
- Seniors with physical impairments, handicaps and disabilities.
- People with mild or serious cognitive impairment or even with dementia.

Concerning the first group, including healthy and active seniors, although there is a strong association between ageing and health outcomes, large groups of seniors in developed countries in Europe, North America, Japan etc. feels to be in good or even excellent health. Obviously, helping older people to remain independent and ageing in place, is very important, for their quality of life. It is also of major interest to health and social services, due to cost savings, over more expensive forms of care, in various institutional settings. This group needs mainly ICT, focused, first, in entertainment, communication and socializing activities, promoting their quality of life and second, on preventive health self-monitoring of basic vital parameters at home (e.g. visual self-inspection of breast for women, blood-pressure, blood-sugar, cholesterol etc.).

Concerning the group of elderly people with chronic diseases, we have to point-out that those physical or mental long-standing conditions require continuous medical care and have usually significant impact on the person's functional capacity and quality of life. They are, either life-threatening (e.g. cardio-respiratory diseases, cancer etc.) or other conditions (e.g. rheumatoid arthritis, osteoporosis, metabolic syndrome etc.) that are not directly lethal, nevertheless, they have serious impact on the health and the well-being of elderly people. As the population ages, the prevalence of chronic diseases and the comorbidities increases, thus, causing great trouble, in the way chronic diseases should be successfully managed.

Elderly people with chronic diseases may stabilize essentially their condition, by adding to their health self-monitoring, in accordance with their physician, parameters specific to their chronic disease, related to the efficiency of medication taken or assistive equipment used.

***Table 1.*** *Some chronic diseases in ageing population frequently appearing also as comorbidities.*

| Addison's Disease | Chronic Obstructive Pulmonary Disorder | Epilepsy | Multiple Sclerosis |
|---|---|---|---|
| Asthma | Chronic Renal Disease | Glaucoma | Parkinson's Disease |
| Bronchiectasis | Coronary Artery Disease | Haemophilia | Rheumatoid Arthritis |
| Bipolar Mood Disorder | Crohn's Disease | Hyperlipidaemia | Schizophrenia |
| Cardiac Failure | Diabetes Mellitus Types 1 & 2 | Hypertension | Lupus Erythematosus |
| Cardiomyopathy | Dysrhythmias | Hypothyroidism | Ulcerative colitis |

Concerning seniors with physical impairments handicaps & disabilities or people with mild or serious cognitive impairment or even dementia, the most important common goal is to ensure independent living, by providing specialized supporting services to individuals, who have impairment (physical, mental, cognitive or sensory impairment) or face other economic or social barriers.

Concerning physical or sensory impairment, important progress has been done, related to CNS implantable micro-devices, exoskeletons for walking (spinal cord injury) etc.

Concerning people with cognitive impairment or even with dementia, beyond pharmaceutical and stem-cells promising R&D outcomes, the share of older people in need of care, living at home, will grow even faster, due to the ageing society.

The Information and Communications Technologies (ICTs) are offering to all these above mentioned categories of ageing population, the strategic platform, upon which, the medical, technical and managerial support are built.

## 3. The Emerging Internet of Things

Most Biomedical equipment are still "stand-alone" units and medical practitioners and allied professionals still need to cooperate closely with each other and operate manually systems, devices and machines, in order to reach reliable Diagnostic inferences and consequently, to deliver appropriate treatment to their patients. On the other hand, there are a lot of emerging technologies during the last five years that allow for "Machine Type Communication, MTC", "Machine to machine communication, M2M" leading to a new "Internet of Things, IoT", enabling a kind of "Machine-Cooperation" without the direct human intervention.

ITU was pioneer, opening the discussion about the Internet of Things (IoT) already in 2005 [10]. The IoT has been defined in Recommendation ITU-T Y.2060 06/2012 [11], as a global infrastructure for the information society, enabling advanced services by interconnecting (physically and virtually) things, based on existing and evolving inter-operable information and communication technologies. Numerous other ITU-guidelines and recommendations followed [12]-[17] and other supporting activities are continuously held [18], clarifying the "rules" of this explosively developing application field.

## 4. The Involvement of the Internet of Things in Active Ageing and Home-Care

We have recently completed an integrated Home-care system that comprises of the following hardware modules and components, as well as, custom developed software, supporting the overall operation [19]-[28].

Vital signs' handling includes:

- Electrocardiogram (ECG).
- Non-invasive arterial Blood-Pressure (NIBP).
- Arterial Oxygen saturation ($SpO_2$).

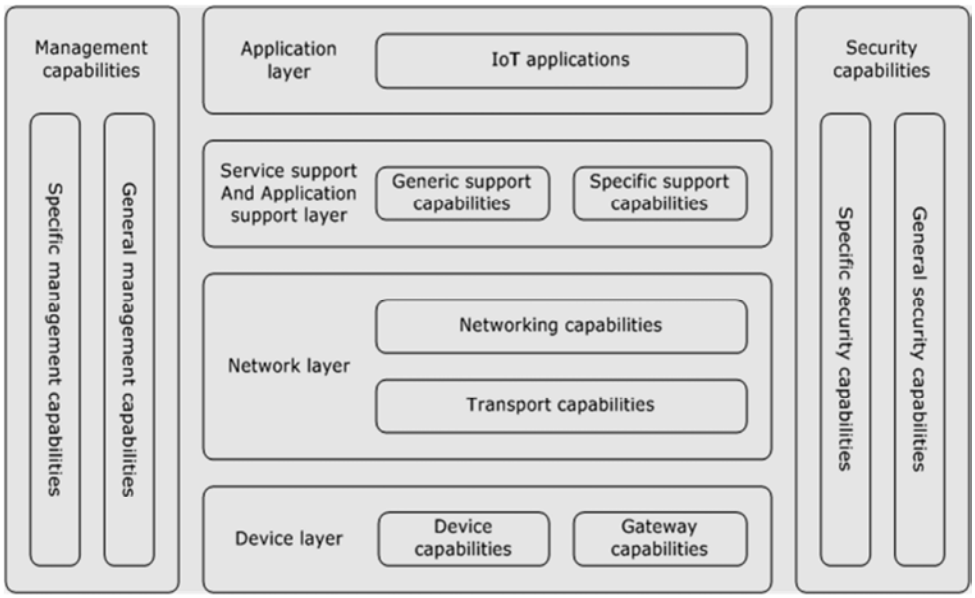


***Figure 3.*** *The ITU-T IOT Reference Model published on June 1, 2016. https://www.linkedin.com/pulse/m2m-iot-survey-various-standards-raja.*

- Respiration Parameters: Respiratory Flow, Airway Pressure, $CO_2$ and $O_2$ concentrations.
- Respiratory Sounds' registration and visualization.
- Bedside Point-of-Care in vitro and in vivo Diagnostics.
- Breast and skin self-inspection and documentation.

Aiming to upgrade our system into a Home-care M2M-Communication application, we have adopted the approach and the terminology of the International Telecommunication Union (ITU) and more specific, the M2M service layer and architectural framework requirements, the Application Programming Interface (API) and Protocols and the Remote patient monitoring/assisted living requirements (RPM/AL).

The information flows from the patient's side at home towards a caregiver. For example, data are transferred from sensors linked to the patient, forming a body area network (BAN), to a gateway that manages the sensors and it can be continuous or periodic, depending on the sensor and the Biosignal types.

The acquired data are stored in a gateway and/or uploaded to a medical information system located in a wide area network. In the gateway, the data are linked to the patient demographics. Caregivers, such as medical doctors, can access the patient's personal information in accordance with privacy and security requirements.

We are attempting presently to develop our own, ITU-compliant M2M platform, indicated in Figure 3 that will include, when fully completed, the following functions: Connectivity Support, Service Enablement, Device Management and Application Support.

The key functional components in the e-health ecosystem for RPM/AL [14] include:

a) The monitored patient;

b) The sensors of the employed devices;

c) A Local Area Network (LAN) that provides the communications between sensors and gateway (e.g. WiFi);

d) A Body Area Network (BAN), enabling communication between sensors and a gateway proximal to the patient;

e) A Gateway that collects and analyses vital data from sensors in a LAN or BAN, and structures them with the personal data of the patient as a medical record;

f) A Wide Area Network (WAN) that offers communication capability for gateways to upload data to a medical information system;

g) A Medical Information System that manages the patient's information uploaded from gateways, stores it, in accordance with security and privacy requirements and manages access to the stored information from caregivers and patients;

h) A Front End Tool that interrogates and displays individual electronic health information from a medical information system, upon a caregiver's request and finally

i) A Caregiver who retrieves and modifies individual electronic health information stored in a medical information system via a front-end tool and gives a feedback to the patient.

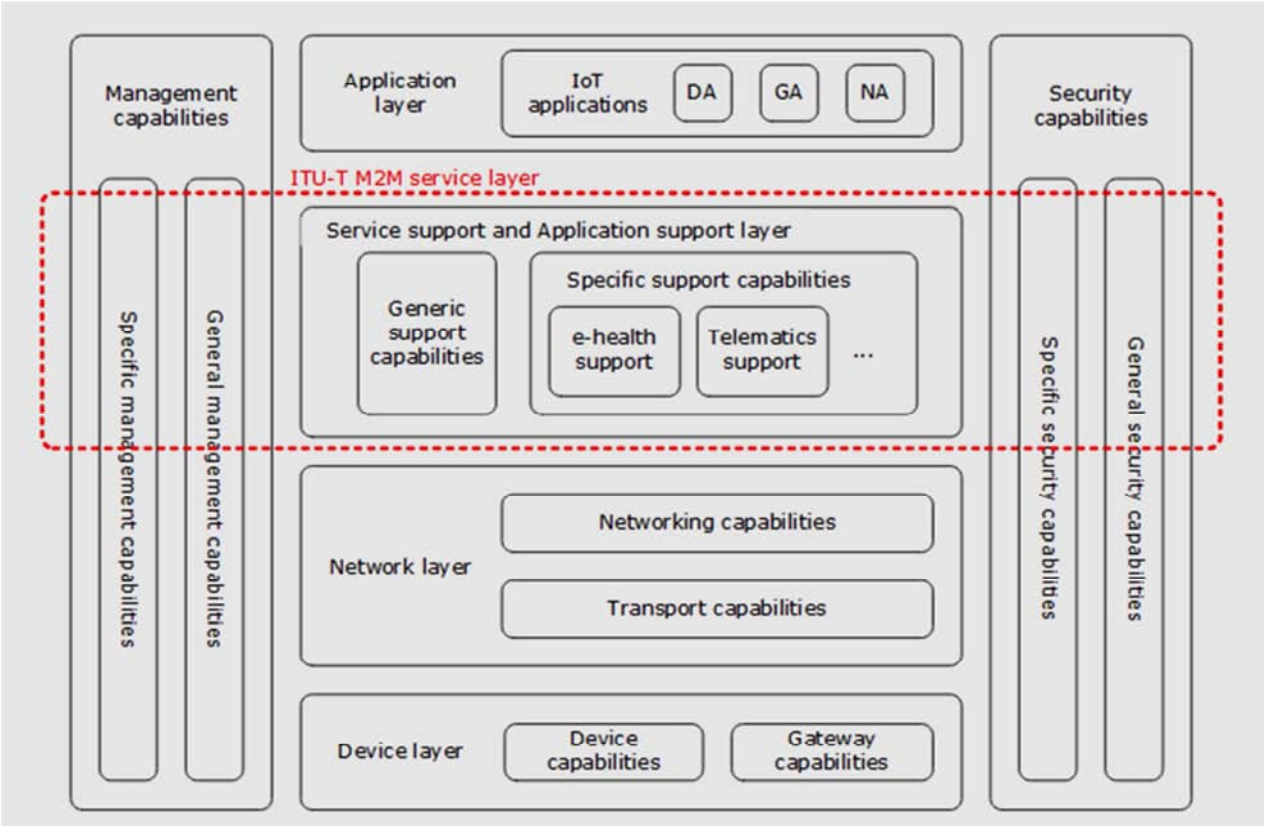


***Figure 4.*** *The ITU-T M2M service layer in the IoT reference model. https://www.itu.int/dms_pub/itu-t/opb/fg/T-FG-M2M-2014-D2.1-PDF-E.pdf.*

In our project we are presently working on the fulfillment of the ITU-T M2M requirements, concerning the service layer architectural framework displayed in Figure 4.

The emerging Internet of things (IoT) constitutes a vision with technological and societal aspects. Concerning the aspect of technical standardization, the IoT can be regarded as a global infrastructure for the information society, enabling advanced services by physically and virtually interconnecting all kind of “things”, based on existing and still evolving interoperable ICTs.

Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes upgrades the use of "things" to offer new services to all “real-world” applications, however, ensuring security and privacy requirements of the said application.

Especially in health-care provided at home, the IoT seems to be able to integrate technologies related to advanced machine-to-machine communication, autonomic networking, data mining and decision-making, quite valuable in the emerging necessity of affordable home health-care and self-inspection, especially for the elderly citizens and their relatives. The home-patient or the fragile senior could belong to an extended, virtually global, social- and medical-care network and his health condition can be supervised and if necessary be supported, at any place and time, with minimal required resources.

In the following paragraph, we shall examine the unlimited potential of these emerging technologies, towards IoT-supported Active Ageing and Home-care, as they are reflected and disclosed on retrieved and processed relevant Industrial Property (IP) Documents, published during the last five years.

## 5. IoT-Supported Active Ageing and Home-Care as Reflected on IP-Documents

Mobility has transformed our society and it is obvious that it will also radically alter medical practice, since mobility is migrating from connecting people to connecting things. Although Medicine is a “conservative” science and thus, healthcare moves much slower than the consumer markets, a fast shift is seamlessly occurring. Medical device manufacturers, up to now, have kept a cardinal position in healthcare.

Partially, the high-priced “big” equipment that brought high profit-rates is gradually changing into a massive market, with lower profit-rates and higher profit-mass. Medical devices are now sharing the health-care market with companies that analyze data to deliver much higher diagnostic accuracy and specificity levels, supporting medical decision making.

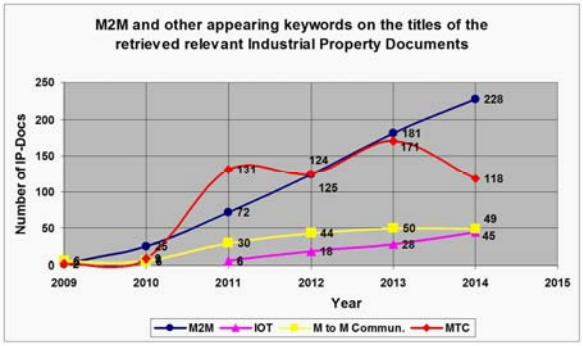


***Figure 5.*** *Example of an Industrial Property Document-mapping that presents the increasing trends of filing in the above mentioned subject-matter.*

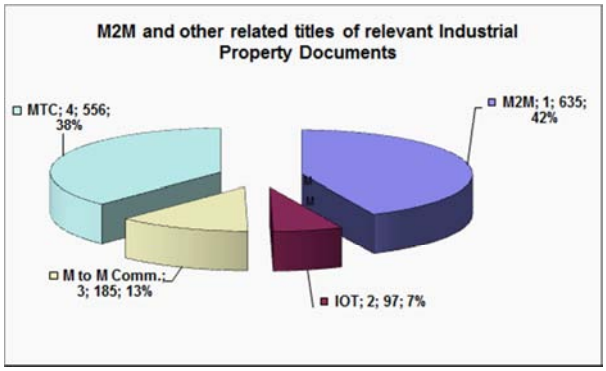


***Figure 6.*** *Distribution of M2M and other related titles of relevant Industrial Property Documents.*

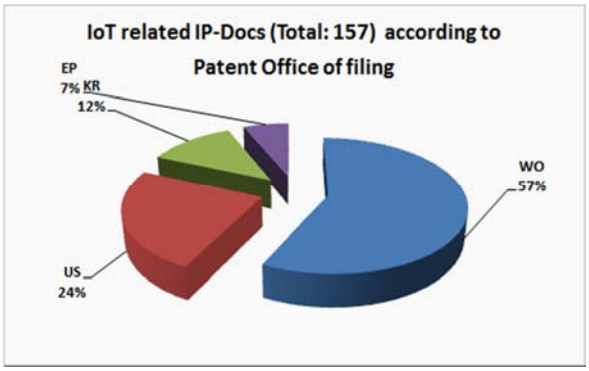


***Figure 7.*** *IoT related IP-Docs (Total: 157) according to Patent Office of filing.*

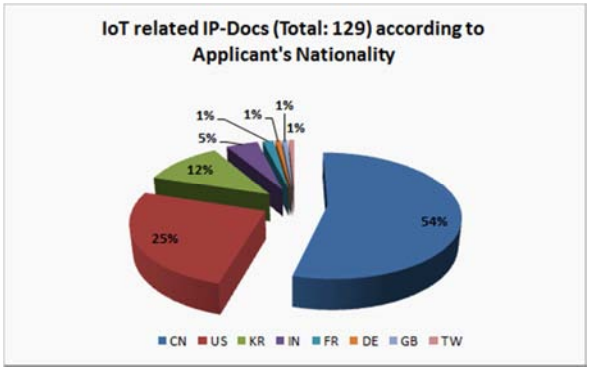


***Figure 8.*** *IoT related IP-Docs (Total: 129) according to Applicant's Nationality.*

The health-care associated IoT, is an emerging medical network of physical objects, equipment or devices (things), connected usually wirelessly to the Internet, which collect relevant data, through appropriate and rather miniaturized sensors, and send and share information that remotely control and manage health-care devices or processes, in order to provide a more beneficial clinical outcome. The Figures 5-8 constitute an IP-Docs mapping that presents the increasing trends of Patent-filing rates in the above mentioned subject-matter "M2M", "MTC", "IoT", Patent Offices of filing and Applicant's Nationalities.

## 6. Ageing Industrial-Economic Progress and Social Welfare Perspectives

It is argued that there is a strong and rather precise correlation between Innovation, expressed in terms of Patent-ownership in a country, the Prosperity of the population of this country and consequently their total life expectancy at birth, in years. That means that IP-documents and more specific, the number of Patents in force, is an accurate prosperity and thus, Active Ageing Index.

In the next Figure 9, the 10 leading in IP countries of the World (2004-2013), concerning the number of Patents in force, are presented. As far as their total life expectancy at birth, in years, is concerned, Japan, France and Switzerland are leading with 83 years, followed by UK (82), S. Korea, Germany and Canada (81) the US (79) China (75) and Russia (70).

The slowly responding IP-related index shows that the explosive increase of the number of Patents in force in China and the high-ranking of Russia, during the last 10 years, is not expressing yet a proportional social progress that would reflect also, better expectations about active aging in both countries.

The emerging major economies (BRICS: Brazil, Russia, India, China and South-Africa) and especially China, make gradually their presence in the systemic Patent Organizations, considering the legal protection of their technological and industrial achievements, as well as, their economic exploitation, of high national priority.

They demand also a not negligible share, in several emerging or even already technologically mature industrial branches (cf. Figures 7-8). These countries, in spite of their economic growth, are still deficient in Health-care and Social Services, as far as, a significant portion of their population is concerned, and especially the elderly people and their perspectives for active and healthy aging.

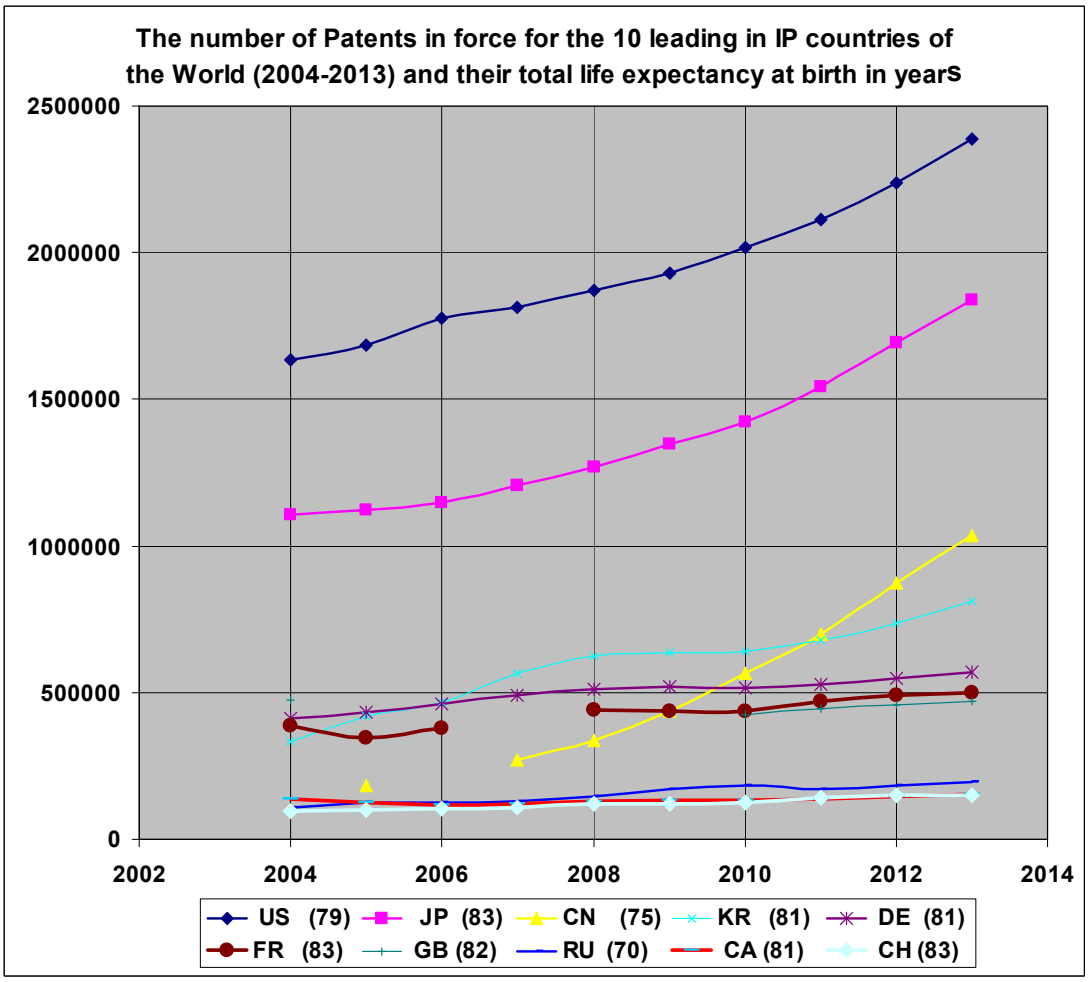


***Figure 9.*** *The number of Patents in force for the 10 leading in IP countries of the World (2004-2013) and their total life expectancy at birth in years.*

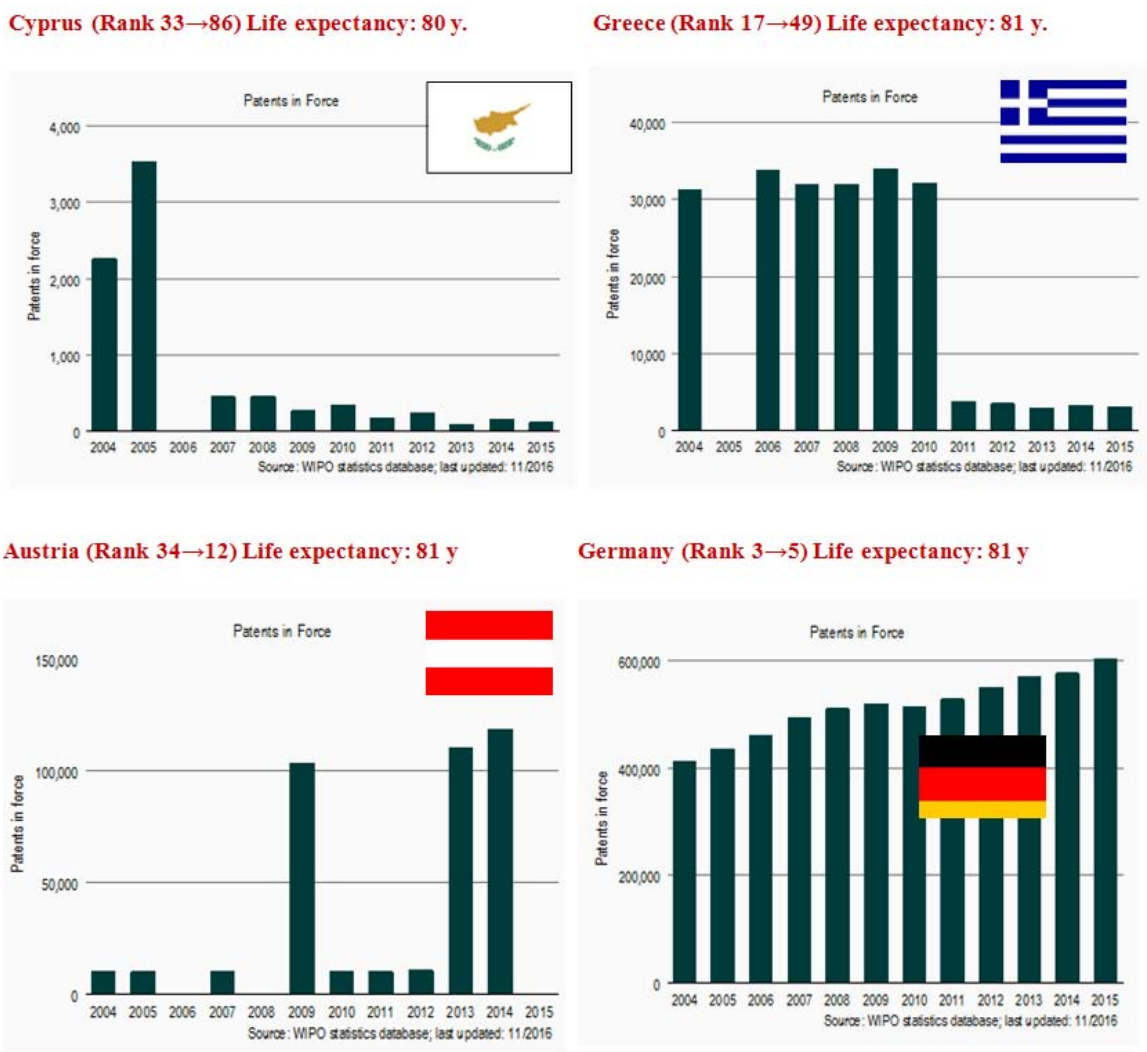


***Figure 10.*** *Innovation potential expressed as worst and best ranking during the years 2004-2015 concerning patents in force and their total life expectancy at birth in years for the considered four countries.*

In a second example, concerning our previously mentioned four countries case-study, Cyprus and Greece have lost their good placements in the world innovation ranking, based on the numbers of patents in force, from 33 to 86 (CY) and from 17 to 49 (GR) respectively.

This is obviously due to the financial crisis of both countries, however, the very slower responding "life expectancy at birth", in years, index, remains still in a very high level, almost identical with the ones of Austria and Germany.

Austria recovers, by the end of 2013, from its worst positioning 34 to rank 12 and Germany remains at the 5th place, behind USA, Japan, China and S. Korea since 2010.

We have attempted to inspect an emerging, correlation, between "successfully ageing", industrial and economic progress and social welfare, for the ageing populations of the "traditional" and the emerging "new" industrial countries and the perspectives of their fruitful cooperation to face these challenges. The above presented examples, and other similar ones, give hints that this correlation is definitely present; however, a lot of work is still needed in this field.

The two central questions are:

- First, the perspectives that these gains in average life expectancy do offer and how they could be realized.
- Second, what challenges arise from the demographic ageing, and how should they be addressed.

The impressive increase in life expectancy and the associated demographic change, for example, a particularly low birth rate, is not limited to Europe and Japan, but reflects rather a global trend. Demographic change has already set in, on other continents too, and is now making even faster progress there.

That means, that a new cardinal activity field and an associated important emerging market is born worldwide, associated to these world population age structure-trends, comparable only to the educational activity. It seems that life prolonging, in order to be worth living, should be accompanied with an enormous medical-managerial, social and economic effort, analogous to the one needed to grow-up children and, and to support them to enter their social and professional life [29]-[31].

These challenges, posed by the ongoing demographic

change, offer also a very appropriate opportunity for a fruitful cooperation, between the EU, the USA, Japan, S. Korea, Australia etc. and the "BRICS" in the field of Health-care and Active Ageing. We have previously mentioned the BRICS-lack in these sectors and a part of their surplus, earned through the industrial explosion, especially in China and India, should be invested for the improvement of the rather poor living conditions, of their own population and especially, older ones.

More specific, the EU has a valuable social experience and an excellent scientific and technical background, related to Health-care and Active Ageing, achieved through the highest social expenditure in the world. This high social expenditure, combined with the transfer of the world industrial production eastwards, is among the main reasons of the present European stagnation. Endeavoring a large-scale cooperation, between EU and the BRICS, concerning Health-care and Active Ageing, is an important and legitimate objective, because it stimulates the prosperity of the ageing populations in these countries, as well as, the economic growth of the Health-care and Active Ageing related industries in Europe, leading to mutually beneficial outcomes.

## 7. Concluding Remarks and Perspectives

Successfully ageing is definitely no *Illusion*; the presented data and the associated Research and Development efforts, corroborate an objective and rapidly emerging social reality. It is also definitely a *Burden*, for most Western governments, because they are not able to ensure the human and material resources, needed to continue the present welfare, for the generations to come and thus, to fulfill the "solidarity duty" for the generation entering now ageing.

But I personally prefer to regard Active Ageing, as a great achievement of the Humanity, to prolong our life-trip. Virtually, an *Opportunity* to understand that only an extravagant and peaceful cooperation, combined with the amazing technologies, developed during the last 50 years, can find the innovation and solidarity trail, leading to a constructive *modus vivendi et cooperandi*, in a multi-divided and controversial world and keeping life meaningful.

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