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Multicriteria evaluation of the Internet of Things potential in health care: The case of dementia care

Nikos Dimitrioglou
Chemical Engineering School
National Technical University of Athens
Athens, Greece
nikosdimitri@mail.ntua.gr

Dimitris Kardaras
Business Informatics Laboratory
Athens University of Economics and Business
Athens, Greece
kardaras@aueb.gr

Stavroula Barbounaki
Merchant Marine Academy of Aspropyrgos
Aspropyrgos, Greece
sbarbounaki@yahoo.gr

***Abstract*— The Internet of Things (IoT) is a rapidly developing field and has the potential to significantly impact the healthcare industry. However, little research has been done in to investigate the IoT potential for seniors with chronic diseases and special needs, such as dementia and Alzheimer patients. It is crucial for decision makers, such as health care services providers, governments, clinics, etc., to be able to assess different types of IoT applications in relation to the specific nature of dementia. This paper utilizes the Analytic Hierarchy Process (AHP) and attempts to develop a multicriteria model in order to evaluate the potential of various IoT technologies applications in dementia care. Six IoT-based healthcare services were selected and compared against two conventional services (i.e. family-based healthcare and assisted living facility), in terms of their effectiveness, safety and patient perspectives. An AHP questionnaire was structured and data was collected and analysed from a group of 12 experts in dementia, who had previously agreed to participate in this study. The results indicate the potential of IoT technologies. However, the importance of conventional dementia care services is still highly appreciated. The design and development of IoT-based services for dementia patients should take into consideration the fact that cognitive dysfunction is an obstacle for using new technologies, thus further development is necessary and new functionality need to be implement for the IoT to be competitive.**

Keywords—Internet of Things; e-Health; Dementia care; Assisted Living; Multicriteria evaluation

I. INTRODUCTION

The Internet of Things (hereinafter IoT) offers many capabilities and therefore has gained vital attention during the past decade. By means of appropriate information and communication technologies, the IoT can enable a whole new class of applications and services [1]. Despite the fact that the term IoT is currently more broadly used, there is no universal definition for the IoT. The core concept is that everyday objects can be equipped with capabilities that will allow them to communicate with one another, as well as with other devices and services over the Internet in order to achieve an objective [2]. Smart objects or things can be defined as entities that have a minimal set of communication functionalities, computing capabilities and means to sense physical phenomena [1].

While the IoT has a great potential and expectations are rising, significant challenges remain to be resolved [3]. For instance, full interoperability among interconnected devices, high degree of smartness, as well as security and privacy of the users and their data are crucial issues [4] and can be accomplished through technology improvement. Additionally, the architecture's resilience to attacks, data authentication, access control and client privacy need to be reinforced [5]. From a business perspective, the cooperation among partners of various industries is needed due to the nature of combining digital technology with physical objects [6]. As a result, entire industry boundaries may need to be redefined, thus reestablishing existing business models, developing a new breed of services and exploiting the potential of services' composition more than in previous years [3].

Nowadays, the IoT is penetrating a wide range of industries including retailing, manufacturing, home appliances, heavy equipment, airlines, logistics, and healthcare [7]. It is estimated that by 2020, the quantity of interconnected devices can reach twenty four billion [8]. Healthcare is an important application sector of IoT [9] and the impact of IoT innovations, although still in its initial stages of development, has been significant [10]. For instance, the IoT is applied in clinical practice to monitor physiological sings of patients and then remotely sending the patient's data to processing centers and decision makers [11]. More specifically, rich information are possessed by networked sensors, either worn on the body or implanted in our living environments [12].

Challenges faced by the health care sector, such as the rapid rising and ageing of the world's population could be addressed by the Health-IoT technologies and services [13]. It is well documented that in the near future the number of retired people will approach the number of working people worldwide [14]. Health services based on IoT technologies can contribute to the reduction in the cost of healthcare, while and overall improve the outcomes, by enabling the individualization of treatment [12]. However, the future development of sustainable innovations in health care practices, should take into

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consideration the interdependencies between technology, human characteristics, and the socioeconomic environment [15].

During the last years, the design and development of Health-IoT services have drawn a considerable amount of attention in the scientific community and across industries [12], [16], [17]. However, little research has been done towards the development of a paradigm designed for seniors with chronic diseases and special needs, such as dementia and Alzheimer. Dementia appears with progressive loss of a person's usual and customary cognitive function from any of several domains [18]. According to [19], a total of 46.8 million people worldwide were estimated to be demented in 2015 and it is estimated that it will be raised to 131.5 million by 2050, particularly in developing countries. It is estimated, that $604 billion was spent on dementia care worldwide in 2010, $420 billion of which in United States and Western Europe [20].

The adaption of IoT in healthcare has the potential to sustain, and even to improve, the current level of support to the elderly people and especially to demented people. Such a paradigm aims to continuously and objectively remote monitor problematic daily activity areas and individually intervene for improving cognitive function and health-related Quality of Life (HRQoL) [21]. Currently, there are various care regimes for dementia patients within the EU. In Greece, the vast majority of demented patients receive care from family members [22], and the state takes over this responsibility only in exceptional cases [23]. A housing trend for older adults, adopted in the Netherlands, is a successful measure that matches the level of care required or the amount of service desired [23].

IoT technology can be integrated in dementia care and have a significant impact on HRQoL and the overall health services' effectiveness. For instance, IoT applications can decrease the healthcare costs, by reducing unnecessary hospital admissions or by improving medication management. Therefore, it is necessary for health care stakeholders such health services providers, governmental organizations, hospitals etc, to be able to assess different types of IoT paradigms with respect to the specific nature of dementia. Despite the potential of IoT applications in dementia care more research is needed towards understanding and measuring the IoT impact on HRQoL. Towards this end, this paper aims at developing a multicriteria model in order to evaluate the potential of various IoT applications in dementia care.

II. HEALTH-IOT

Global ageing and the related prevalence of chronic diseases are currently a common concern [14]. In the last decades, the proportion of older persons aged 60 years or over has globally been increased and is expected to reach 22% of the global population in 2050 [13]. Aging of world's population is directly correlated to a number of new health problems challenging current healthcare systems [24]. Furthermore, prescription medication noncompliance is another issue that causes an annual rise of hospitalizations and poses a substantial burden on healthcare systems [25]. Smart healthcare could play a significant role through embedding sensors and actuators in patients and their medicine for monitoring and tracking purposes [11].

One important trend in the healthcare industry is self-management of chronic diseases, as it has the potential to generate significant benefits in a fundamentally changing environment [26]. It is expected that in the near future, the way healthcare is currently provided will be transformed from hospital-centered, firstly to hospital-home-balanced in 2020th, and then ultimately to home-centered in 2030th [27]. Therefore, it is imperative for the healthcare industry to develop sophisticated and useful health-related technologies and services by exploiting information and communication technology, and apply them directly in the home environment [14].

The application domains of IoT can be grouped into three main categories: Medical and Healthcare Industry, Pharmaceutical Industry and Independent Living.

A. Medical and Healthcare Industry

In the near future, new technologies that allow integration and intercommunication between different devices through the Internet will revolutionize healthcare services [28]. For instance, diabetic comas and hearth attacks can be detected and prevented, as patients with existing illness (diabetes, heart disease, etc.) could be monitored with sensors [29]. Rapidly increasing demand of daily monitoring with onsite diagnosis and prognosis is driving homecare solutions to integrate more and more sensing and data processing capacities for tri-axis accelerometer, electrocardiogram, blood pressure and oxygen saturation, respiration oxygen saturations, blood sugar concentration, body surface temperature, etc. [25]. Moreover, IoT can potentially be useful in analyzing behavior that might be indicative of depressive symptoms [30]. Furthermore, lack of availability of important patient-related medical information is a common cause for many errors occurring in healthcare [31]. Enabled by the global connectivity of the IoT, all the health care information, such as diagnosis, recovery, medication and even daily activity, can be collected, managed and utilize more efficiently [32].

B. Pharmaceutical Industry

The pharmaceutical industry is a domain, in which security and safety is of outmost importance. According to [4], attaching smart labels to drugs has many potential benefits as it enables tracking through the supply chain and status monitoring with sensors. It is claimed that smart labels can be valuable by: i) monitoring drugs and/or discarding them in case of violation during transport; ii) detecting of counterfeit products; and iii) informing consumers of dosages and expiration dates. Furthermore, allergy interactions, as well as serious and fatal Adverse Drugs Reactions (ADRs) could be prevented. Moreover, an intelligent medicine packaging (iMedPack) is proposed in [14] that utilizes two key technologies: RFID and Controlled Delamination Materials (CDM). Using iMedPack could be beneficial by solving medicine misuse problem, improving pharmaceutical noncompliance situation, and making the daily task as easy and smart as possible.

C. Independent Living

Participation in social and economic life and good quality of life for people with disabilities can be achieved by using IoT technologies [32]. For instance, residences equipped with sensors can assist impaired people and resolve their social isolation [33]. Specific interfaces are designed for automatically controlled manipulation of the home devices, and assistive devices are developed to improve living conditions at home [32]. Special assistance devices, for instance, are devices for indoor navigation and electro-mechanical devices for movement assistance (powered wheelchairs and specialized lifting devices). Furthermore, paraplegic persons can have muscular stimuli delivered via an implanted start thing-controlled electrical simulation system in order to restore movement functions [4].

In recent years researchers have developed a variety of assistive technologies based on a new paradigm called Ambient Assisted Living (AAL) [34]. AAL is an emerging multidisciplinary field aiming at exploiting information and communication technologies in personal healthcare and tele-health systems for countering the effects of growing elderly population [35]. However, the efficient combination and management of heterogeneous things or devices in the ambient intelligence domain is still a tedious task, and it presents crucial challenges [36]. In [21], the authors designed a system for continuous monitoring of daily living activities and for enhancing cognitive function and HRQoL.

III. RESEARCH MOTIVATION AND METHODOLOGY

The potential of IoT technologies in dementia care is expected to be of significant importance for both the patients and the health services providers. However, IoT applications in dementia care are still in their infancy, yet their potential is not fully understood and formalized, thus more research is needed. This paper aims to develop a multicriteria model in order to measure the potential of IoT in dementia care and compare it against the traditional methods that are most often currently in use. It utilizes the Analytical Hierarchy Process (AHP) in order to capture medical experts' opinions and to quantify the relative importance of IoT.

Figure 1 illustrates the steps of the methodology adopted for the construction of the IoT in Dementia Care evaluation model.

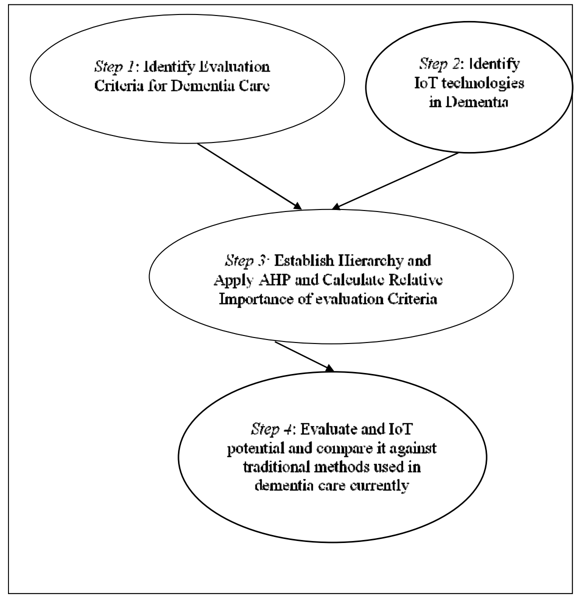

Fig. 1, The proposed methodology for the construction of IoT applications in Dementia Care evaluation model.

Step 1: *Identify Evaluation Criteria for Dementia Care*

The cardinal criteria used in this study are effectiveness, safety and patient perspectives which are proposed by [43], [44].

The effectiveness of the dementia care system is defined as relating to the improvement of HRQoL, improvement of the overall health status and reduction to acceptable limits of mortality due to dementia- and age-related risks [43], [45]. HRQoL is an assessment of how the individual's well-being may be affected over time by a disability, disorder or disease. According to [46], health-related quality of life of a demented person's quality of life (DEMented Quality of Life i.e., DEMQoF) is based on five domains: daily activities and looking after yourself, health and well-being, cognitive functioning, social relationship and self-concept. From this perspective, the dementia care system aims to improve well-being, strengthen cognitive function, enable social relationships, reinforce self-esteem and assist in daily activities. Health status is a concept that includes measures of functioning, mental wellbeing and physical illness. From this perspective, the dementia care system aims to consult and support, manage medication, promote physical activity, improve sleep patterns and maintain a balanced diet. The two most common causes of death, for people with early to middle stages of dementia, are severe pneumonia and ischemic heart due to immobility and malnutrition [18]. Furthermore, falls are a very common among seniors as a cause for accidental death [47].

The safety of the health care system is related to the avoidance or reduction to acceptable limits of potential harm or damage from healthcare management or the environment in which health care is delivered. The main related issues with safety are risks from the environment, as well as medication and diagnostic errors. Risks from the environment can be categorized as domestic and external. Domestic risks are potential hazards that are related with the home or facility environment. Improved lightening, surveillance, smoke and fire detection can contribute for a safe and dementia friendly environment. External risks are defined as potential hazards that are mainly pertinent to wandering. A medication error can be defined as a failure in the treatment process, involving prescribing, dispensing or administration that may lead to harm the patient [48]. For instance, medication can have side effects, including dizziness, which could increase the risk of a fall. Diagnostic errors can be defined as a missed, delayed and wrong diagnosis that are induced by human, as well as system factors [49].

The patient perspective is related to the perception of the individual of the healthcare paradigm, including the patient acceptance of the treatment [43]. For instance, the dementia care system aims to reinforce confidence in the treatment and achieve patient's satisfaction. Confidence in the treatment is strongly related to security and privacy, reliability, as well as responsiveness [50]. Patient's satisfaction is mainly associated with complexity, empowerment, as well as comfort [51], [52]. The criteria and sub-criteria are represented with explanations in Table I.

TABLE I. CRITERIA AND EXPLANATIONS

Criteria	Explanation
Improve Quality of Life	Improve well-being Strengthen Cognitive Function Enable Social Relationships Reinforce Self-esteem Assist in daily activities
Improve Health Status	Consult and Support Manage Medication Promote Physical Activity Improve Sleep Patterns Maintain Balanced Diet
Decrease Mortality	Reduce age-related risks Reduce dementia-related risks
Reduce Environment risks	Reduce domestic risks Reduce external risks
Identify errors	Identify medication errors Identify diagnostic errors
Reinforce Confidence	Security and privacy Reliability Responsiveness
Achieve Satisfaction	Complexity Empowerment Comfort

Step 2: *Identify IoT technologies in Dementia*

Two conventional healthcare services and six IoT technologies are taken into consideration the IoT in Dementia Care evaluation model to be contrasted as selection alternatives in AHP hierarchy. Both (HRQoL) Criteria, IoT technologies and the two conventional services are used to establish the AHP hierarchy. The hierarchy was validated by in-depth interviews with two experts with many years of experience in dementia care.

- **Social Assistive Robotic**: Social Assistive Robots (SAR) are defined as the intersection between Social Interactive Robots and Assistive Robots. SARs can assist patients with dementia by maintaining residual cognitive affective and enhancing global functioning [37]. The main advantage is that it provides time-expected individualized cognitive and social interaction and facilitates ongoing monitoring and companionship [38]. The proposed paradigm is a robot with four types of sensors: tactile, light, audio, and temperature, with which it can perceive individuals and its environment. Moreover, it is equipped with a screen, allowing video calls with healthcare provider and it is able to learn and to adapt to its environment.
- **Ambient Assisted Living**: Ambient Assisted Living aims to counter the effects of growing senior population by exploiting information and communication technologies in healthcare [35]. However, this emerging field has crucial challenges, such as the efficient combination and management of heterogeneous things or devices in the ambient intelligence domain [36]. AAL can offer people with disabilities support, good quality of life, as well as participation in the social and economic life [32]. The proposed paradigm is a home monitoring system based on a combination of distributed motion and contact sensors and autonomous devices [35], [39], [40].
- **Wearable Device**: Unobtrusive all-day and any-place health, mental and activity status monitoring can be accomplished by a wearable device [16]. Specifically, a wearable device can compromise various types of small physiological sensors, transmission modules and processing capabilities. To achieve non-invasive and continuous monitoring of health, wireless sensors must be in a reasonable weight and size [41]. The proposed IoT paradigm is a watch or a bracelet and it implements functionalities such as wireless communication, automatic fall detection, manual alarm triggering, data storage, and a simple user interface [40].
- **Implanted sensor**: To measure health parameters, such as glucose or body temperature, biosensors must be in close contact with the patient's skin, and in some cases even inside the body [41]. Moreover, an implantable biosensor enables the health parameters monitoring in a continuous and unobtrusive way and thus it is an important type of biosensor. The proposed IoT paradigm is an implanted device and it implements functionalities such as vital signs monitoring (body temperature, heart rate, blood pressure).
- **Hearable**: Impaired hearing can be countered with external assistive devices, such as earphones [32]. The proposed IoT paradigm is an ear-worn, flexible, low-power device. It implements functionalities such as wireless communication, a tracking system against wandering, heart rate monitoring and fitness tracking.
- **Cognitive orthotics – Gamification**: It is well documented that the elderly cognitive decline can be

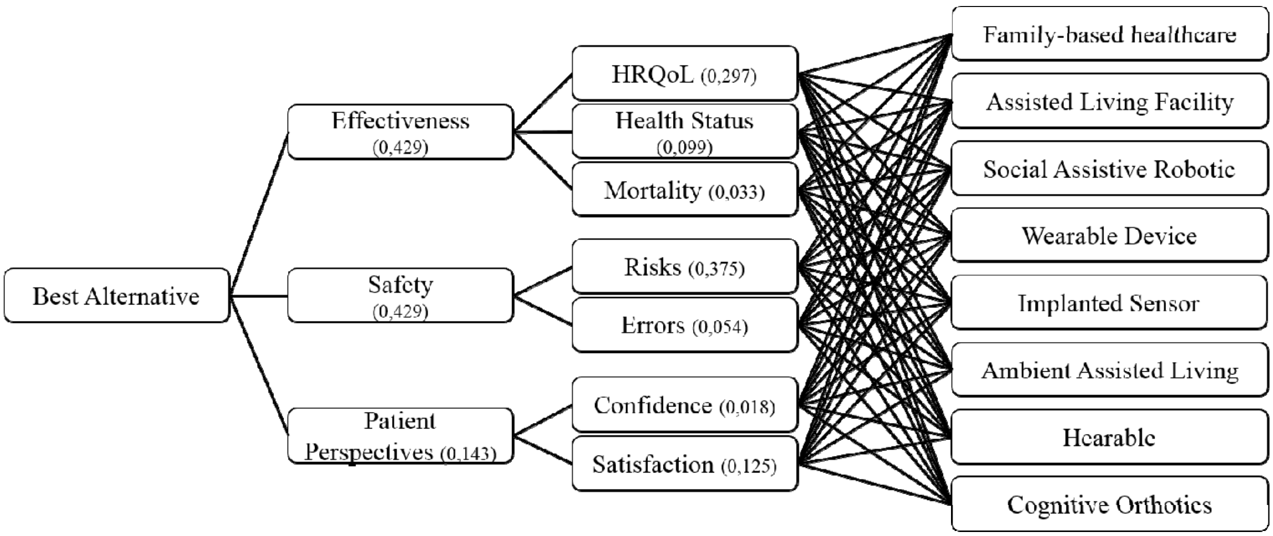

Fig. 2, AHP Model

attenuated by cognitive training. In [42], it is presented how surface computing can be used to introduce a model for cognitive training and cognitive rehabilitation associated with elderly individuals. The proposed paradigm consists of a surface table application, cognitive training games and a social activation application.

Step 3: *Establish Hierarchy and Apply AHP and Calculate Relative Importance of evaluation Criteria*

The AHP was utilized in order to capture the experts' data and calculate the relative importance of the evaluation criteria. The completed AHP model is represented in Figure 2. (Related weights' calculations are illustrated in Section IV. Empirical Study). The evaluation criteria are (1.) Effectiveness, (2.) Safety and (3.) Patient Perspectives, and the sub-criteria (1.1.) HRQoL, (1.2.) Health Status, (1.3.) Mortality, (2.1.) Risks, (2.2.) Errors, (3.1.) Confidence and (3.2.) Satisfaction.

Step 4: *Evaluate and IoT potential and compare it against traditional methods used in dementia care currently*

The AHP model is used to compare and contrast the sic IoT technologies considered in this study with the two conventional dementia care methods.

A. Method: The Analytical Hierarchy Process

The criteria are mutually compared for n × (n-1)/2 times if there are n criteria. Experts' opinions were obtained by adapting a nine point scale recommended by Saaty [43], [44]. Preferences between alternatives are given as equally, moderately, strongly, very strongly, or extremely preferred. The pairwise comparisons can be represented as:

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \quad (1)$$

where aij represents the value that experts compare the criterion i with the criterion j. The relative weights of the criteria in this matrix is estimated by comparing the priority of the criteria. The eigenvalues and eigenvectors are computed with the following equation:

$$A \cdot w = \lambda max \cdot w, \quad (2)$$

where w is the eigenvector of the matrix A, and λmax is the largest eigenvalue of the matrix A.

To examine the reliability of judgments in the pairwise comparison, the consistency of the matrix is estimated. The Consistency Index (CI) and the Consistency Ratio (CR) are defined as:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (3)$$

$$CR = \frac{CI}{RI} \quad (4)$$

where n is the number of criteria being compared in this matrix, and RI is the Random Index. The average consistency index of a randomly generated pairwise comparison matrix of similar is presented in Table II.

TABLE II. RANDOM INDEX (RI)

N	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

IV. EMPIRICAL STUDY

One-to-one interviews were conducted for the purposes of this research during November, 2016 and December, 2016. Each interviewer was informed beforehand of the research object and the interview duration. Six neurologists and six psychiatrists, with expertise in dementia, were invited to evaluate the relative importance of the criteria and relative preference to the alternatives. The reliability of the judgments was examined by calculating the CR of each matrix. Finally, there was a total of twelve submitted questionnaires. However, the final priority results were extracted from four questionnaires, as these only fulfilled the requirement of consistency (CR<0,1). The following Table III shows the four experts' consistent replies.

TABLE III. PAIR-WISE MATRIX FOR CRITERIA

Goal: Best alternative	Effectiveness	Safety	Patient Perspective
Effectiveness	(1.000, 1.000, 1.000, 1.000)	(3.000, 1.000, 3.000, 1.000)	(3.000, 3.000, 1.000, 3.000)
Safety	(0.333, 1.000, 0.333, 1.000)	(1.000, 1.000, 1.000, 1.000)	(1.000, 3.000, 0.200, 3.000)
Patient Perspective	(0.333, 0.333, 1.000, 0.333)	(1.000, 0.333, 5.000, 0.333)	(1.000, 1.000, 1.000, 1.000)
Goal: Effectiveness	HRQoL	Health Status	Mortality
HRQoL	(1.000, 1.000, 1.000, 1.000)	(3.000, 5.000, 3.000, 5.000)	(5.000, 7.000, 5.000, 7.000)
Health Status	(0.333, 0.200, 0.333, 0.200)	(1.000, 1.000, 1.000, 1.000)	(3.000, 3.000, 3.000, 3.000)
Mortality	(0.200, 0.143, 0.200, 0.143)	(0.333, 0.333, 0.333, 0.333)	(1.000, 1.000, 1.000, 1.000)
Goal: Safety	Risks	Errors	
Risks	(1.000, 1.000, 1.000, 1.000)	(5.000, 1.000, 1.000, 7.000)	
Errors	(0.200, 1.000, 1.000 0.143)	(1.000, 1.000, 1.000, 1.000)	
Goal: Patient Perspective	Confidence	Satisfaction	
Confidence	(1.000, 1.000, 1.000, 1.000)	(0.333, 0.333, 1.000, 0.143)	
Satisfaction	(3.000, 3.000, 1.000, 7.000)	(1.000, 1.000, 1.000, 1.000)	

The relative weights of the criteria are presented in Table IV, also in Figure 2.

TABLE IV. WEIGHTS OF CRITERIA

Criteria	*Weight*	*Rank*	*Sub-criteria*	*Weight*	*Rank*
Effectiveness	0,429	1	HRQoL	0.297	2
			Health Status	0.099	4
			Mortality	0.033	6
Safety	0,429	1	Risks	0.375	1
			Errors	0.054	5
Patient Perspective	0,143	3	Confidence	0.018	7
			Satisfaction	0.125	3

The details of the outcome calculations are presented below. The seven dementia care services are denoted by A_{fam}, A_{ALF}, A_{SAR}, A_{WD}, A_{IS}, A_{AAL}, A_H and A_{CO}.

TABLE V. AGGREGATED PAIR-WISE MATRIX FOR ALTERNATIVES

HRQoL	A_{fam}	A_{ALF}	A_{SAR}	A_{WD}	A_{IS}	A_{AAL}	A_H	A_{CO}
A_{fam}	1.000	3.201	3.409	1.627	2.141	1.088	1.848	3.708
A_{ALF}	0.312	1.000	2.590	2.590	2.590	1.968	2.280	3.201
A_{SAR}	0.293	0.386	1.000	1.000	1.524	0.386	1.316	1.158
A_{WD}	0.615	0.386	1.000	1.000	1.136	0.386	0.553	1.884
A_{IS}	0.467	0.386	0.656	0.880	1.000	0.340	0.669	0.760
A_{AAL}	0.919	0.508	2.590	2.590	2.943	1.000	1.732	3.708
A_H	0.541	0.439	0.760	1.809	1.495	0.577	1.000	2.141
A_{CO}	0.270	0.312	0.863	0.531	1.316	0.270	0.467	1.000
Health Status	A_{fam}	A_{ALF}	A_{SAR}	A_{WD}	A_{IS}	A_{AAL}	A_H	A_{CO}
A_{fam}	1.000	3.201	3.708	3.000	2.280	2.817	3.708	2.817
A_{ALF}	0.312	1.000	1.968	2.943	1.699	1.732	3.409	2.943
A_{SAR}	0.270	0.508	1.000	1.495	1.627	1.000	1.136	1.732
A_{WD}	0.333	0.340	0.669	1.000	1.316	0.447	0.669	0.439
A_{IS}	0.439	0.589	0.615	0.760	1.000	0.340	0.669	0.577
A_{AAL}	0.355	0.577	1.000	2.236	2.943	1.000	1.000	1.000
A_H	0.270	0.293	0.880	1.495	1.495	1.000	1.000	0.760
A_{CO}	0.355	0.340	0.577	2.280	1.732	1.000	1.316	1.000
Mortality	A_{fam}	A_{ALF}	A_{SAR}	A_{WD}	A_{IS}	A_{AAL}	A_H	A_{CO}
A_{fam}	1.000	4.583	3.708	1.848	2.817	3.873	2.480	4.213
A_{ALF}	0.218	1.000	3.409	4.787	4.787	2.432	3.637	3.948
A_{SAR}	0.270	0.293	1.000	0.669	1.316	0.760	1.136	1.732
A_{WD}	0.541	0.209	1.495	1.000	0.615	1.316	1.495	1.968
A_{IS}	0.355	0.209	0.760	1.627	1.000	2.590	1.316	2.280
A_{AAL}	0.258	0.411	1.316	0.760	0.386	1.000	1.136	2.141
A_H	0.403	0.275	0.880	0.669	0.760	0.880	1.000	2.280

A_{CO}	0.237	0.253	0.577	0.508	0.439	0.467	0.439	0.577
Risks	A_{fam}	A_{ALF}	A_{SAR}	A_{WD}	A_{IS}	A_{AAL}	A_{H}	A_{CO}
A_{fam}	1.000	1.848	4.787	3.482	3.000	2.280	4.486	5.544
A_{ALF}	0.541	1.316	2.590	2.590	2.141	2.141	3.482	4.583
A_{SAR}	0.209	0.386	1.000	1.158	1.732	1.136	2.236	2.590
A_{WD}	0.287	0.386	0.863	1.000	1.136	0.809	1.732	1.732
A_{IS}	0.333	0.467	0.577	0.669	1.000	1.401	0.809	1.210
A_{AAL}	0.439	0.467	0.880	1.236	0.714	1.000	1.495	2.280
A_{H}	0.223	0.287	0.447	0.577	1.236	0.669	1.000	1.495
A_{CO}	0.180	0.218	0.386	0.577	0.827	0.439	0.669	1.000
Errors	A_{fam}	A_{ALF}	A_{SAR}	A_{WD}	A_{IS}	A_{AAL}	A_{H}	A_{CO}
A_{fam}	1.000	1.136	1.316	1.968	1.158	1.968	3.344	3.708
A_{ALF}	0.880	1.000	2.432	1.316	1.000	2.590	5.544	4.583
A_{SAR}	0.760	0.411	1.000	0.760	0.669	1.316	2.943	2.236
A_{WD}	0.508	0.760	1.316	1.000	1.000	1.732	2.590	2.236
A_{IS}	0.863	1.000	1.495	1.000	1.000	3.409	3.873	4.213
A_{AAL}	0.508	0.386	0.760	0.577	0.293	1.000	1.732	2.141
A_{H}	0.299	0.180	0.340	0.386	0.258	0.577	1.000	1.291
A_{CO}	0.270	0.218	0.447	0.447	0.237	0.467	0.775	1.000
Confidence	A_{fam}	A_{ALF}	A_{SAR}	A_{WD}	A_{IS}	A_{AAL}	A_{H}	A_{CO}
A_{fam}	1.000	4.304	5.664	3.270	4.880	5.544	3.482	6.853
A_{ALF}	0.232	1.000	4.213	2.010	3.482	3.708	3.482	4.213
A_{SAR}	0.177	0.237	1.000	2.943	3.637	2.590	3.344	2.590
A_{WD}	0.306	0.497	0.340	1.000	2.590	1.316	1.000	1.210
A_{IS}	0.205	0.287	0.275	0.386	1.000	0.541	0.577	0.699
A_{AAL}	0.180	0.270	0.386	0.760	1.848	1.000	1.495	1.000
A_{H}	0.287	0.287	0.299	1.000	1.732	0.669	1.000	0.760
A_{CO}	0.146	0.237	0.386	0.827	1.432	1.000	1.316	1.000
Satisfaction	A_{fam}	A_{ALF}	A_{SAR}	A_{WD}	A_{IS}	A_{AAL}	A_{H}	A_{CO}
A_{fam}	1.000	6.435	6.435	5.544	6.853	6.031	6.853	5.544
A_{ALF}	0.155	1.000	4.213	4.486	5.544	3.873	4.213	2.943
A_{SAR}	0.155	0.237	1.000	1.968	4.213	1.732	1.732	1.316
A_{WD}	0.180	0.223	0.508	1.000	2.817	0.577	0.577	0.467
A_{IS}	0.146	0.180	0.237	0.355	1.000	0.258	0.293	0.253
A_{AAL}	0.166	0.258	0.577	1.732	3.873	1.000	2.280	1.732
A_{H}	0.146	0.237	0.577	1.732	3.409	0.439	0.299	1.000
A_{CO}	0.180	0.340	0.760	2.141	3.948	0.577	1.000	1.000

The importance weights for each alternative derived from the AHP analysis are represented in Table VI. The relative weights of alternatives are shown in Table VI and are not included in Figure 2 for clarity reasons. The ranking per criterion and the final ranking of the alternatives are presented as well. The two conventional services, i.e. family-based healthcare and assisted living facility, ranked first and second respectively. AAL ranked first among IoT paradigms, while Assistive Robotic ranked second and Wearable Device ranked third. Moreover, Cognitive orthotic is the least preferable among healthcare professionals. More specifically, our preliminary results indicate that:

- From effectiveness perspective, the two conventional alternatives, i.e. family-based healthcare and assisted living facility, ranked first and second respectively. Furthermore, AAL ranked first among IoT paradigms, while Hearable ranked second and Assistive Robotic ranked third. The less effective is Cognitive orthotics in accordance with the experts' opinions. From this results, AAL has the potential to be a reliable alternative in the near future and overcome Assisted Living Facilities.

- From safety perspective, the two conventional alternatives, i.e. family-based healthcare and assisted living facility, ranked first and second respectively. Moreover, Social Assistive Robotic ranked first among IoT paradigms, while AAL ranked second and Wearable Device ranked third. According to experts' judgment, Cognitive orthotics contribute the less in patient's safety. According to experts, it seems that Social Assistive Robotic is a promising IoT technology and can enhance the safety of the patient.

- From patient perspective, the two conventional alternatives, i.e. family-based healthcare and assisted living facility, ranked first and second respectively. Additionally, Assistive Robotic ranked first among IoT paradigms, while AAL ranked second and Cognitive orthotics ranked third. Finally, the experts indicate that the Implanted Sensor has the least positive impact on patient's experience. Perception of the individual and the acceptance of the treatment is important for the successful establishment and thus the use of Social Assistive Robotic in dementia care is very promising.

TABLE VI. RANKING PER CRITERION AND FINAL RANKING

Alternative	Criterion						Final Ranking	
	Effectiveness		*Safety*		*Patient Perspective*			
	Score	*Rank*	*Score*	*Rank*	*Score*	*Rank*	*Score*	*Rank*
Family-based	0,111	1	0,126	1	0,064	1	0,301	1
Assisted Living Facility	0,085	2	0,092	2	0,029	2	0,206	2
Social Assistive Robotic	0,036	5	0,045	3	0,013	3	0,094	4
Wearable Device	0,033	6	0,040	5	0,007	7	0,079	5
Implanted Sensor	0,029	7	0,039	6	0,004	8	0,072	7
Ambient Assisted Living	0,066	3	0,040	4	0,011	4	0,117	3
Hearable	0,040	4	0,026	7	0,007	6	0,074	6
Cognitive orthotics	0,027	8	0,020	8	0,009	5	0,057	8

V. Discussion and Conclusions

The Health-IoT technologies and services promise to address the challenges faced by the health care sector, such as the rapid rising and ageing of population. The main objective of this study is to evaluate Internet of Things applications in dementia care. Furthermore, the endeavor was to develop a multicriteria assessment model in order to compare various IoT-based healthcare services with conventional services in the EU. In particular, a Dementia Care Selection model was developed by using AHP method and Internet of Things paradigms, benchmarked to conventional alternatives, which were subsequently evaluated by health professionals. The AHP method is particular useful to quantify expert's opinion and to rank various healthcare model alternatives. It is suggested that, future research should apply this selection model to verify its feasibility.

The ranking per criterion and the final ranking of the alternatives indicates that IoT technologies are not yet competitive, in accordance to expert's judgment. Considering the introduction stage of IoT technologies in healthcare industry, this result could be reversible. Specifically, AAL have the potential to overcome assisted living facilities, as it is very effective and ranked first among IoT paradigms in accordance with our results. However, at this initial stage significant investment from Health-IoT industry partners is required in order to achieve technology improvement and better outcomes. Furthermore, physician technology acceptance is another issue to be settled, as it is a critical factor for a successful implementation of IoT in healthcare. Systematic clinical trials of IoT technologies with active participation of healthcare professionals can be used to increase acceptance.

In conclusion, from this these preliminary results, it seems that some IoT-based healthcare models need to offer new functionalities, in order to be competitive. For instance, Cognitive orthotics ranked fifth from patient perspective, while it was characterized as less effective. Furthermore, the design and development of IoT-based services for dementia patient should take into consideration the fact that cognitive dysfunction is an obstacle for using new technologies. Therefore, AAL and Assistive Robotic, that have advanced embedded intelligence in comparison with other IoT technologies, were evaluated as the best IoT-based alternatives.

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