BCUBE – Assistive Customizable Bathroom Module for Physically Impaired Individuals

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As a response to forecasted aging of societies, as well as to increasing costs for institutional admissions and healthcare home aids, new solutions have to be developed in order to support the elderly into "aging in place". Advanced technologies, including automation, object intelligence and service oriented technology await to be integrated into elderly's houses, in order to better support impaired seniors into performing the ADLs (Activities of Daily Living). However, the reluctance of elderly to welcome new technologies, the costly and time-consuming process of retrofitting traditional houses, as well as the presence on market of cheaper home modifications impedes the advanced technology into entering the market of Ambient Assisted Living for elderly. The current paper will focus on the bathroom environment, the location labeled as most hazardous, as well demanding for a wider range of complex tasks and activities, in a senior's house. BCUBE was thought as an alternative type of bathroom, made up of a platform, easily deployed in traditional housing, that can seamlessly support advanced technologies on market (eg, sensors, actuators, MEMS etc.), as well as bathroom furniture components allowing for automated functionalities to support different levels of seniors' disability. The result is a compact, modular and customizable cabin, unifying together all the complexity that otherwise will have to be distributed all around the house that supports certain bathroom disabilities of elderly.

***Keywords**: Ageing Society, Home Care, BADLs, Assistive Technology, Mass Customization*

INTRODUCTION

Western Europe is currently going through a phase of demographic change, the so called "aging of society". Due to increased life expectancy on one hand, as well as baby boomers generation reaching their retirement age on the other hand, almost one fifth of Germany's current population (21%) is at least 65 years old. Following the same trend, by 2060, every third German person will be of retirement age[1]. Most of the seniors still, or would prefer to, live in their houses as they get older. Yet, due to various age related physical, sensory or cognitive impairments, nowadays Germany has over 2.1 million seniors in need of care[2]. Apart from personal desire, evidence shows that "aging in place", when properly assisted and secured, helps to prevent or reduce the severity of age-related impairments[3].

According to several authors[4,5], the older adults encounter difficulties into performing ADLs (Activities of Daily Living) mostly in the bathroom, which is identified as the most unsafe space in the seniors' home environment[5]. Table 1 shows the BADLs (Bathroom Activities of Daily Living), which are associated with age-related physical disabilities[6]. The difficulty into performing one or several BADLs is a strong indicator of an eventual long-term nursing home admission[7], increased hospital usage, need for a home aide service, as well as a primary predictor of morbidity, and ultimately – mortality[8], mainly due to falls and near-falls, which represent the fifth leading cause of death among the older individuals[9]. Circa 15% of falling episodes among the elderly happen in the bathroom, which makes it a common location for casualities[4]. Previous studies[10] concluded that the reasons behind a fall are usually a combination of three domains of factors: personal (age-related impairments), environmental hazards (eg, slippery floor), and behavioral factors (ADL that are regarded as dangerous for seniors). The personal risk factors have been subject of much assessment involving older people[11], and the most predicting ones were those related to lower extremity impairments, as shown in the Fig. 1.

Risk Factor	Mean Relative Risk*
Muscle weakness	4.4
History of falls	3.0
Gait deficit	2.9
Balance deficit	2.9
Use of assistive devices	2.6
Visual deficit	2.5
Arthritis	2.4
Impaired activities of daily living	2.3
Depression	2.2
Cognitive impairment	1.8
Age > 80 years	1.7

Fig.1 The most common personal risk factors predicting falls, identified in 16 different studies[11]

As a response to environmental hazards, as well as a means for developing safe behaviors, rehabilitation specialists have opted for home modifications, meant

Table 1. BADLs associated with disability

Utility	Activity
Bathtub / Shower	Undressing / dressing
	Helping get in / out of the bathtub / shower
	Rinsing
	Soaping
	Body drying
	Body creaming
	Body inspection
WC	Helping sit down on / stand up from the toilet
	Washing the body parts
	Toilet disinfection
Sink	Hand washing
	Oral hygiene
	Hair care
	Face care
Miscellaneous	Access to the bathroom / movement inside the bathroom
	Cleaning of the bathroom
	Safety control
	Handling emergency situations

to maximize safety, independence and the ease of use. However, following the new developments among assistive technologies, the home modifications can be brought to a new level of automation, intelligence and network supported assistance, which would enhance the functionality of traditional modifications and would provide a safe environment for elderly to age in place. Yet, the conventional built environment and furniture does not always allow for an easy "upgrade" to an advanced automated and intelligent environment[12], as well as elderly are not always eager to accept an evident change of settings within their homes. Thus, the options for an almost "invisible", easy to mount, and fast intervention is to be discussed. Moreover, due to the complexity of each individual's situation and multi-morbidity, it is very hard to develop a standardized system that would respond to every current or further impairment, as well as to ongoing change within the disability state of an older individual. Thereafter, an "inclusive design" should be considered. For housing, the inclusive design is a new trend pointing at a predictive design, able to adapt, or permit for further adds-on, in order to meet the future, unpredictable at times, needs[13]. Finally, along with the development on market of service robotics, special attention should be paid to integration of robotics within building components and furniture[12], as a part of AAL (Ambient Assisted Living), especially if speaking about the partial or total replacement of a home aid input, which would spare the elderly, as well as their care giver, the financial and emotional burden.

The purpose of the given paper is to: (I) develop a prototype of a platform, specifically designed for the bathroom environment, aimed at providing a seamless environment, as well as an adaptable plug and play system, for existing on market assistive technologies and further developments; (II) propose a basic kit of automated bathroom furniture, supported by the platform, developed for seniors suffering from mobility dysfunctions - the most imminent indicator of possible injuries or fatality (Fig. 1); (III) discuss a possible business strategy, aimed at facilitating the wide spread and procurement of the given system.

The following sections of the paper will present: (I) a review of the state of art of bathroom assistive technologies for older adults; (II) BCUBE - a possible solution to the issues previously discussed and a rough implementation of one of the BCUBE's proposed functionalities; (III) the options for the mass customization of the BCUBE; (IV) a business strategy aimed at facilitating the wide spread and procurement of the BCUBE; (V) a discussion of results; (VI) the conclusion and the future research.

RELATED WORKS

As a response to age-related impairments, assistive technologies are usually employed to restore independency and safety. The umbrella term "assistive technology" covers a broad range of devices from the very simple, conventional, low-cost ones to the most advanced monitoring and communication technologies. One study[14] classified the existing devices into four distinct categories: Telecare (eg, alarms, movement sensors etc. to provide personal safety), Telehealth (remote disease monitoring), Equipment to facilitate physical rehabilitation (eg, interactive rehabilitation), Environmental design (eg, grab rails, raised toilet seat etc.). For a personalized environment, able to meet different requirements and provide safety and independence on a multiple level, a carefully customized combination of the up-mentioned categories is required, mainly due to the presence of very specific multi-morbidity for every older individual[14]. When talking specifically about the bathroom environment, the elderly are generally opting for conventional assistive devices and home modifications, mainly due to lower costs, easier installment and more available information. Common home modifications[15] include (I) adding supplement equipment to existing bathroom settings (eg, nonskid mat or abrasive stripes, grab bars, handled shower spray, shower seat, transfer bench, raised toilet seat[8,16]); (II) rearranging items (eg, moving furniture); (III) changes in the building structure (less common, eg, adding a first floor bathroom, widening the bath-

room etc.). According to Naik (2005)[8], conventional bathroom adaptations facilitated reduction in health care expenses, as well as lowered the need for home aide services and institutional admission. However, different studies report varying degrees of usage of the already installed devices - from 46% to 87%[17]. The reasons behind the underutilization of assisting devices are discussed in several studies. One of the most common reason is that of an eventual decline or improvement in the disability state of the individual[18], which does not go well with the rigid mechanism of the conventional bathroom equipment. Another reason is that of the devices being unsuitable for the patient's disability in the first place, due to a limited choice or degree of customization, or due to limited available information[17]. Other identified reasons where those related to feelings of embarrassment to use an assistive device and lack of instructions to use them correctly[17]. Some of the assisting equipment may be a danger itself, if not used or positioned correctly; for instance, the grab bars might present themselves an environmental hazard in case of a fall[19].

Following the current trends, telecare and telehealth are gaining popularity, especially among younger generations who want to support their elderly parents. However, there is still not very clear evidence about the acceptance of the new technology among the nowadays older generation[15]. A telecare study recognized the elderly being worried about being remotely supervised[20], especially if talking about the bathroom environment, where privacy has a significant role. Moreover, it is highly possible that the current elderly generation is less familiar with available complex technology and therefore less likely to accept it in their daily life. According to Brooke (2004)[21], robotic systems should be integrated into assistive devices for elderly. For instance, a Japanese company developed a so called washing machine for humans, where the individual is soaped, rinsed and dried, without any need of the individual's or a care giver intervention. The main driving force for Japanese developments are those related to costly local health care aides, as well as a significant expected increase in elderly population. However, the given robotic systems did not acquire an extended market for several reasons: high price, reluctance of elderly to trust robotics and hardship in maintaining (Nagamachi, 2014)[22]. The lack of purchase motivation is mainly due to the fact that elderly are often frightened by the robotic motion and activity, which significantly decreases their willingness to accept them (Nagamachi, 2014). On another note, the privacy, independence and security the given machines offer are a big reason why an elderly would prefer to use it. According to Brooke (2004), elderly who dared to test the "washing machine" gave a positive feedback and had a good experience. Nagamachi (2014) suggests that a better older human / machine interaction could be obtained through greater attention to ergonomics and settings that are familiar to elderly.

Thereafter, more attention should be paid to a seamless integration of the complex robotic systems in the familiar, existing, conventional assistive bathroom equipment and furniture, as well as to provide greater flexibility and mass customization to the overall system, through the means of a unified platform that would allow for easy plug and play and in time adaptability of the robotic equipment and furniture. A similar concept was developed, as a part of an R&D project[12], where a service unit was designed as a seamless robotic system, to embed MEMS (microelectromechanical systems), sensors, actuators etc., responsible for functionalities needed for the smart home care. The service unit was to be easily deployed in existing houses, "upgrading" the conventional environment to a smart home. However, to the best of our knowledge, the service unit had a rather general approach, and was not further specifically adapted to the bathroom settings.

CONCEPT AND IMPLEMENTATION

Based on previous considerations and developments, the given paper presents an approach to "upgrading" an elderly conventional bathroom environment to a higher level of AAL, by means of a unified platform and subsequent bathroom furniture and equipment easily attachable to it. The bathroom furniture was carefully designed in order to externally resemble conventional bathroom settings as much as possible.

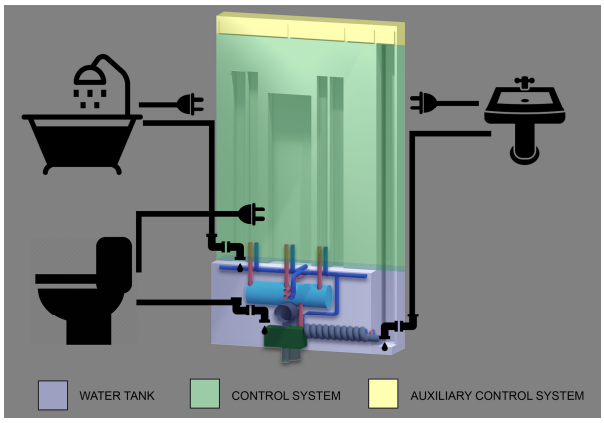

Fig. 2 The functional core, made of three parts

The Functional Core

The main component, the so called "Core" (Fig. 2) is a functional wall (2400 mm x 1180 mm) designed to be easily deployed in a conventional bathroom, or anywhere else in the house. The Core is made up of three parts: (I) the lowermost part is an integrated water saving system tank, that was specifically designed for facilitating an easy plug and play of the

sewage system of the bathroom furniture; the water tank has one connection to the grid water only and one connection to the drainage pipe; (II) the middle part is a platform meant to unify together all the micro controller systems of the bathroom furniture, as well as provides the structural robustness for supporting the physical add-ons; (III) the upper most part is reserved for telecare and telehealth technology. A floor for optimized drainage is attached to the wall component.

The following components, attachable to the functional Core, are integrated systems of various assistive functionalities, that, according to different amount of automation, account to different levels of physical disability, in the way that components themselves can be customized according to each patient's needs, at any time. Also, the components themselves might be attached all at once, or one by one. The easy control of the bathroom furniture was assured by means of pre-programming settings (eg, shower cycle, sink's positions etc.) and let the elderly only control the settings he is highly familiar with (eg, water pressure, water temperature etc.). An easy mountable cabin enclosure is available in case the bathroom will be relocated in any other part of the house (Fig. 10).

The WC Component

The WC Component has an inclusive design, to facilitate different levels of functionalities. The possible add-on functions span from low to high level of automation, according to the degree of physical impairment of the elderly: robotic toilet seat for assisting the process of standing up / seating down; automatic water flush; automatic wash of the body parts; automatic disinfection, etc. The functions will come up as boxes that can be attached or removed to / from the main skeleton - the toilet, according to disability evolution of the patient (Fig. 3).

Fig. 3 The WC component, along with its possible functionalities

The Shower Component

The shower component is made up of a vertical and side water sprays, for a maximum coverage of the human body. The sprayers will perform the soaping and rinsing task, while the integrated body dryer will substitute the towels (Fig. 4). The whole cycle can be pre-programed, choosing the temperature, the water pressure and the timing, so that the elderly can start the process with the same ease as starting a conventional washing machine. The whole cycle of "bathing" will happen gradually, while the user sits in the same position and can carelessly enjoy the process. Just like in the case of WC components, the functionalities can be added or removed.

Fig. 4 The Shower component, along with its possible functionalities

The Sink Component

The robotic sink is an alternative proposal that is able to perform vertical, horizontal and rotational movements, in order to better adapt to the user needs, as well as offer a wider range of functionality according to position. Fig. 5 presents some possible positions, where the sink can serve for individual use, as well as facilitates the intervention of a care giver when needed. The desired position can be easily pre-programmed via a Bluetooth device, while associated to a certain activity, in order to facilitate the easy control: the final user will have to press the button associated with the activity he / she wants to perform, and the sink will take its position. The given functionality was tested through the means of a scaled physical model, as presented in the next paragraph.

Implementation

As mentioned above, the sink component can be easily controlled by a Bluetooth device. An actual demonstration of the given concept was performed through the means of a rough scaled physical model. For the lifting mechanism, a 360-degree servo motor FS5103R, a rack and a gear were used, in order to obtain the vertical movement of the scaled physical model of the sink. For the sake of simple control, an Android user-friendly interface was designed through the means of App Inventor2. The interface was randomly set to three positions (up, down and middle). The Bluetooth receiver connected to the servo motor allowed for easy controlling of the vertical movement when a button was pressed. The motor was actuated

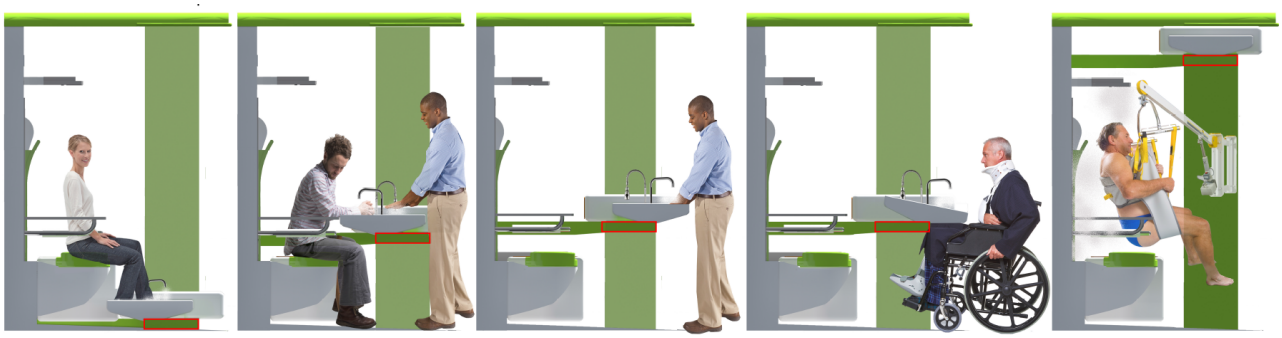

Fig. 5 The different possible positions of the sink and functionalities associated with them

via an Arduino board. For safety reasons, an IR sensor was placed underneath the sink for collision avoidance. In case of an obstacle the lifting mechanism of the sink will immediately stop and a LED light would start flashing. It will start again when the obstacle is out of the pre-set range.

MASS CUSTOMIZATION

The main focus of the up-mentioned design proposal was the adaptability of the bathroom environment not only to different scenarios of individuals with physical disability, but also to eventual negative or positive further evolution of the disability of the same individual. For that reason two levels of customization were proposed. First level is the Core and the possibility to choose the required / desired bathroom furniture and equipment, in order to obtain a customized layout. Second level is the bathroom furniture that acts as the skeleton for possible functionalities (eg, body drier, automatic toilet disinfection, side soaping etc.) that would stand for, or assist, the BADLs associated with disability (Table 1), in this way decreasing or substituting the need for a care giver input. Some functionalities were already thought of and described above, while others can be further found and developed (Fig. 7).

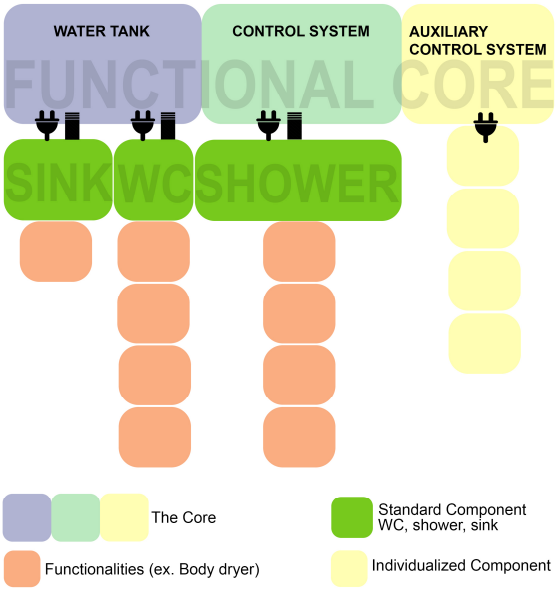

Fig. 7 The options for the mass customization

BUSINESS STRATEGY

Due to the fact that the BCUBE could reach costs beyond the individuals' / companies possibilities, a need to look for potential external funding for the future customers was imperative.

Apart from facilitating an easy plug and play system for pipes, the integrated water saving system tank was developed for opening new possibilities on the target market as well. The given system is an upgraded version of the one developed by an Australian company[23] and, according to them, the system is capable of saving up to 70% of water and 60% of energy, annually. The system captures the grey water coming from the usage of the sink or shower and forwards it to a recycling system: instead of the water going down the drain it goes through a special filter[23] that permits the real time water recycling. Due to the fact that the recycled water is rather warm, less energy needs to be spent in order to re-heat it. Once the shower is over, the water goes automatically to the toilet tank to be drained, so the next person to shower / use the sink will not use the recycled water from the previous one. Also, the functional core has the role of monitoring and controlling the water / energy use. Due to pre-programed showers, automatic soap sprayer, real time water recycling and usage of grey water for the toilet wash, the water consumption is much better controlled and therefore reduced. Also, the functional core will keep track of water / energy usage and would keep the user posted about the situation.

Given the reduction into water and energy consumption of the bathroom module, a similar project could be of relevance: Solarcity[24], the biggest solar panels supplier in the USA, was partly founded by the US government due to their energy saving policies. Therefore, the individual consumers would receive government funding (30% of the cost of the product) for acquiring the solar panels, and therefore, for entering the national program of renewable energy. Same way, the possible customers could be encouraged to acquire the BCUBE, by persuading the government to fund them, according to their level of impairment or disability, as a part of the national program of water and energy saving. Also, instead of

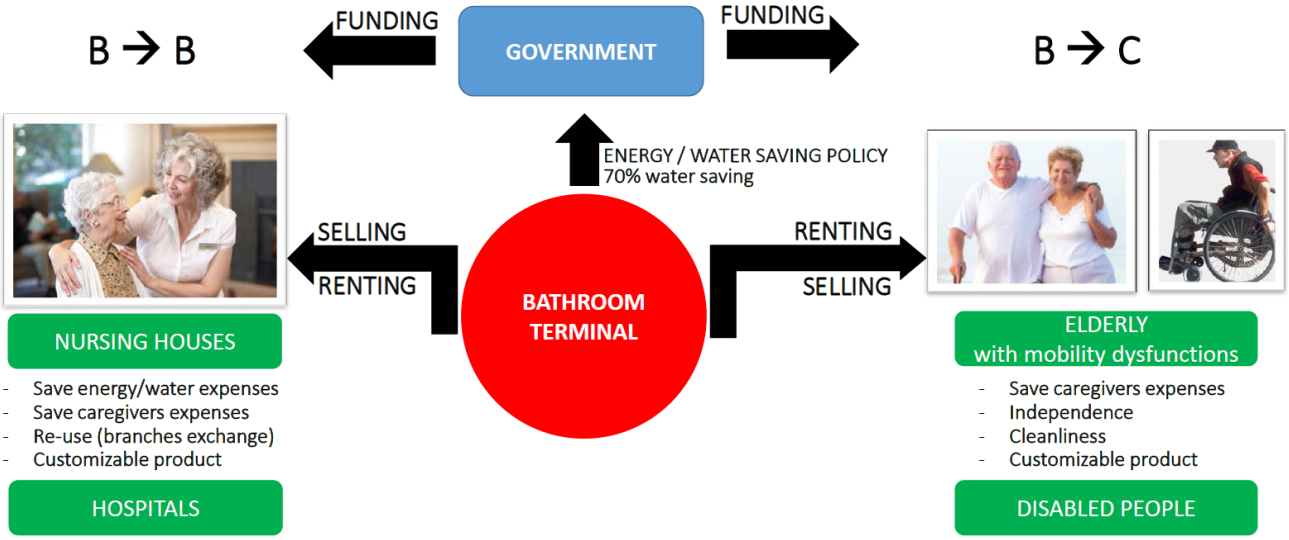

Fig. 8 The business strategy illustrated

selling the BCUBE, the possibility of renting it should be considered, and again, to persuade the government to provide a special subvention, which will represent a certain percentage of the monthly rent. At the end of the life span of a BCUBE, the functional core could be refurbished and re-used for the next costumer. Apart from receiving funding to acquire the bathroom module, the customer, apart from saving funds on water and energy consumption, will save upon the expenses coming with hiring the caregiving personal. That would account for a significant money saving, if we talk about nursing houses or hospitals (Fig. 8).

Discussion

Based on previous findings, elderly people are more likely to have conventional bathroom fittings and equipment standing for their disabilities. A well-positioned aid or adaptation can be very beneficial to disabled elderly people. However, faulty aids are of little use or might be plain dangerous. Moreover, most of the aids are of a standardized nature, as well as are not responsive to eventual changes in initial disability. Therefore, in time, most of the elderly become either dependent on constant care or are constrained to move to specialized nursing institutions. Automation, intelligence and network supported assistance is able to significantly enhance the role of home assisting equipment, as well as better adapt to individual cases. Yet, it is not very clear the level of acceptance of the given technologies by the final users - the elderly, seldom not familiar with current technological trends. Also, the existing houses are not always easy to reconfigure or "upgrade". Thus, a compromise is needed. The BCUBE tried to offer a solution through the means of a unified platform to "collect" and "hide" all the technical part, as well as allowing for different system configurations. Moreover, several levels of automation permit to upgrade the system when more support is needed. The bathroom furniture was carefully designed in order to externally resemble conventional bathroom settings as much as possible, or any other settings already familiar to elderly (eg, pre-programmed shower acting as washing machine).

The outcome was a compact bathroom cabin (Fig. 9), which minimizes the individual's input into performing de BADLs. According to one study[25], active, vigorous elderly are more prone to injuries or falls than the frail, static ones, due to higher exposure to risks. Though the active life style for the elderly should be promoted, the bathroom environment, as the most hazardous location in the house, should minimize the activities, at least the hazardous ones.

Fig. 9 The BCUBE

There is not a sharp value regarding the cost of the system, or the possible expenses reduction on an individual or national level, due to the usage of the BCUBE. However, some assumptions could be made. Possible reduction of expenses could be encountered in following domains: (I) expenses related

to institutional admissions, hospitals or nursing houses, due to the fact that the BCUBE has the potential of keeping the elderly at home for a longer time and / or preventing injuries; (II) expenses related to hired qualified homecare aids, as the BCUBE was aimed at partly replacing the eventual input of a caregiver through the means of automation; (III) expenses related to qualified personnel assisting elderly in nursing houses, due to the fact that assistance into performing BADLs is one of the hardest both on a physical, as well as emotional level; (IV) expenses related to water and energy consumption, due to the presence of a prototype of a water saving system tank, as well as due to a higher control over the usage of water (eg, pre-programed showers etc.).

Conclusion and Further Research

The BCUBE (Fig. 10) is a response to forecasted aging of societies, as well as to increasing costs for institutional admissions and healthcare home aids on one side, and as a means of integrating advanced technologies, including automation, object intelligence and service oriented technology within the home environment, on the other side. Moreover, the BCUBE, due to its inclusive design, was meant to be adaptable and responsive to different typology of disabilities, as well as “evolve” in time, if needed, to new conditions. The working environment for the BCUBE is the bathroom, one of the most hazardous locations of the seniors’ houses. The result is a compact, modular and customizable cabin, unifying together all the complexity that otherwise will have to be distributed all around the house that supports certain bathroom disabilities of elderly. The overall system is made up of a platform, easily deployed in traditional housing, that can seamlessly support advanced technologies on market (eg, sensors, actuators, MEMS etc.), as well as bathroom furniture components allowing for automated functionalities to support different levels of seniors' disability.

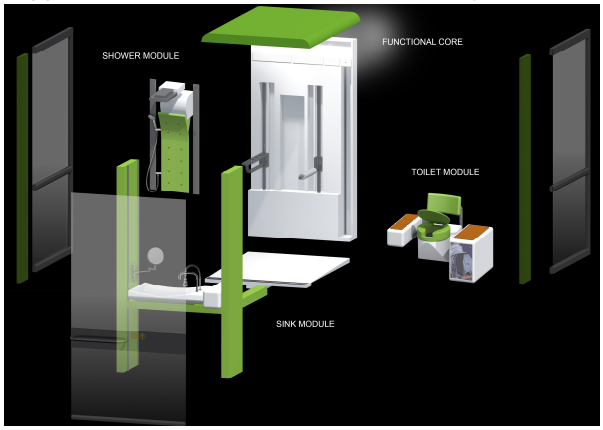

Fig. 10 The exploded BCUBE: the functional core, the wc, shower and sink components, the enclosure

The final users’ acceptance of the system is not yet very clear given the lack of any experimental work so far. The next proceedings would be further detailing of each component, physical prototyping and laboratory testing along with the final users, the elderly.
Additional efforts should be made into better understanding the possible configurations of the system and methods of easy assembly (the way the main platform interacts with components, and the components with their add-on functionalities).

References

1. Haustein, T., Mischke J., "Older People in Germany and the EU", Federal Statistical Office of Germany, 2011
2. Social Security at a Glance, Federal Ministry of Labour and Social Affairs of Germany, 2015
3. Kranz., M., Linner, T., Ellmann, B., Bittner, A., Roalter, L., "Robotic Service Cores for Ambient Assisted Living", In: 4th International Conference on Pervasive Computing Technologies for Healthcare (Pervasive Health 2010), pp. 1-8, München, Germany, March 2010
4. Aminzadeh F., Edwards N., Lockett D., Nair R., C., "Utilization of bathroom safety devices, patterns of bathing and toileting, and bathroom falls in a sample of community living older adults", *Technology and Disability*, 13(2): 95-103, 2000
5. Afifi, M., Al-Hussein, M., "Integrated approach to elderly-friendly home bathroom design", *Gerontechnology*, 13(2): 165, 2014
6. Barrett, S., "Personal Care Tasks", North Dakota Family Caregiver Project, North Dakota State University, 2003
7. Gill, T., M., Allore, H., G., Han, L., "Bathing Disability and the Risk of Long-Term Admission to a Nursing Home", *Journal of Gerontology: Medical Sciences*, Vol. 61A, No. 8, 821-825, 2006
8. Naik, A., D., Gill, T., M., "Underutilization of Environmental Adaptations for Bathing in Community-Living Older Persons", *Journal of the American Geriatrics Society*, 53: 1497-1503, 2005
9. Rubenstein, L. Z., "Falls in older people: epidemiology, risk factors and strategies for prevention", *Age and ageing*, 35. Suppl. 2: ii37-ii41, 2006
10. Connell, B., R., Wolf, S., L., "Environmental and Behavioral Circumstances Associated with Falls at Home Among Healthy Elderly Individuals", *Archives of physical medicine and rehabilitation*, 78.2: 179-186, 1997
11. Arnold, C. M., "Fall risk in older adults with hip osteoarthritis: decreasing risk through education and aquatic exercise", Diss. University of Saskatchewan, Saskatoon, 2008
12. Linner, T., Kranz, M., Roalter, L., Bock, T., "Compacted and Industrially Customizable Ambient Intelligent Service Units: Typology, Examples and Performance", In: The 6th International Conference on

Intelligent Environments - IE'10, Kuala Lumpur, Malaysia, July 2010
13. Metz, D., "Innovation to prevent dependency in old age", *British Medical Journal*, 320: 460-461, 2000
14. Robinson, L., Gibson, G., Kingston, A., Newton, L., Pritchard, G., Finch, T., Brittain, K., "Assistive technologies in caring for the oldest old: a review of current practice and future directions", *Aging Health*, 9(4): 365-375, 2013
15. Ahn, M., "Older people's attitudes toward residential technology: The role of technology in aging in place", Diss. Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 2004
16. George, J., Binns, V., E., Clayden, A., D., Mulley, G., P., "Aids and adaptations for the elderly at home: underprovided, underused, and undermaintained", *BMJ*, 296(6633): 1365-1366, 1988
17. Smith, R., Quine, S., Anderson, J., Black, K., "Assistive devices: self-reported use by older people in Victoria", Australian Health Review, 25(4): 169-177, 2002
18. Parker, M., Thorslund, M., "The Use of Technical Aids Among Community-Based Elderly", *The American Journal of Occupational Therapy*, 45(8): 712-718, 1999
19. Sveistrup, H., Edwards, N., “How Effective Are Bathtub Grab Bars for Stopping a Fall When You Lose Your Balance”, Socio-economics Series 07-016, 2007
20. Magnusson, L., Hanson, E., J., "Ethical issues arising from a research, technology and development project to support frail older people and their family carers at home", *Health Soc. Care Community*, 11(5): 431–439, 2003
21. Brooke, J., "Japan seeks robotic help in caring for the aged", *Caring: National Association for Home Care magazine*, 23.7: 56-59, 2004
22. Nagamachi, M., "Ergonomic aspects for assisting facilities to elderly people", *Gerontechnology*, 13.2: 70, 2014
23. http://www.recyclingshower.com.au/, last visited 30.07.2015
24. http://www.solarcity.com/, last visited 29.07.2015
25. Lord, S., R., Menz, H., B., Sherrington, C., "Home environment risk factors for falls in older people and the efficacy of home modifications", *Age and ageing*, 35(suppl 2), ii55-ii59, 2006