

Healthcare at Home. Spatial Solutions and Integrated Enabling Technologies for Aging in Place

Cristiana Cellucci

Department of Architecture and Arts, Iuav, University of Venice, Venice, 2196, 30123 Italy

Abstract: Within the past decade, advances in medical technology, the desires and complex care needs of an ageing population, and innovative care delivery models have initiated a shift from providing care in hospitals to outpatient settings. And more recently, the acceleration and amplification of these factors is pushing healthcare options even further from the traditional inpatient and outpatient settings towards acute and subacute care in the home. This has led the medical community to look toward providing more tools and methods of care that patients can access safely right from home and the designers to think as the homes of the future will be flexible to support both an array of devices to provide a healthcare delivery and the humanization and personalization of the domestic space. In light of the changing housing demand aimed at a predominantly elderly population, and awareness of the strong impact that aging of the population has on care, on the costs of health services, on the lives of the elderly and on the maintenance of their conditions of independence, and the most recent investments of the National Plan for Resilience and Recovery to relocate care from hospitals to local structures and even to homes themselves, the paper investigates the issue of the adaptability of the home to the needs of elderly people and to the different care conditions to encourage aging in place.

Key words: Flexibility, patient-centred design, aging in place, universal design, healthcare at home, customization.

1. Ageing in Place: The New Frontiers of Home Design

Recent research trends on the interdependence between space, health and lifestyles of healthy cities and Urban Health and the peculiarity of the Age-Friendly City and Aging in Place¹ approaches deriving from the main changes characterizing the contemporary world² imply a rethinking of the concept of health – which adds to the objective dimension of care the subjective dimension of prevention and well-being – and of the social and health organization, which from the hospital-centred outlook approaches the daily life of individuals through a network of territorial structures (community

homes, clinics) down to homes themselves (Fig.1).

The physical, perceptive and emotional proximity of assistance in everyday life acquires a prevalent and particular meaning in the care of elderly people in their own homes [1], interpretable not only in an exclusively healthcare context through tools and methods of care accessible safely directly from home, but also in the design of physical space through solutions to make living spaces safer and more usable and accessible for elderly people and solutions to adapt homes to the care and devices necessary to guarantee adequate home healthcare, preserving the character of humanization/ personalization of the domestic space.

Corresponding author: Cristiana Cellucci, assistant professors, research fields: architecture technology and built environment.

¹ The term Health City refers to an international program that aims to propose synergistic health and sustainable development strategies, which include Urban Health actions for the integration of health into urban planning. The quality of the living, urban and social context is therefore essential in promoting the liveability of a place and the state of health of the

population, in particular the elderly, as supported by the international Age-Friendly Cities and Communities program, promoted by WHO in 2006, from which the term Age-Friendly Cities derives.

² The transformations that come into play in the topic of space-health interdependence are an increase in the elderly population and lonely elderly people, an increase in chronic degenerative diseases and a consequent impact on the costs of health services (Vetrano, 2023).

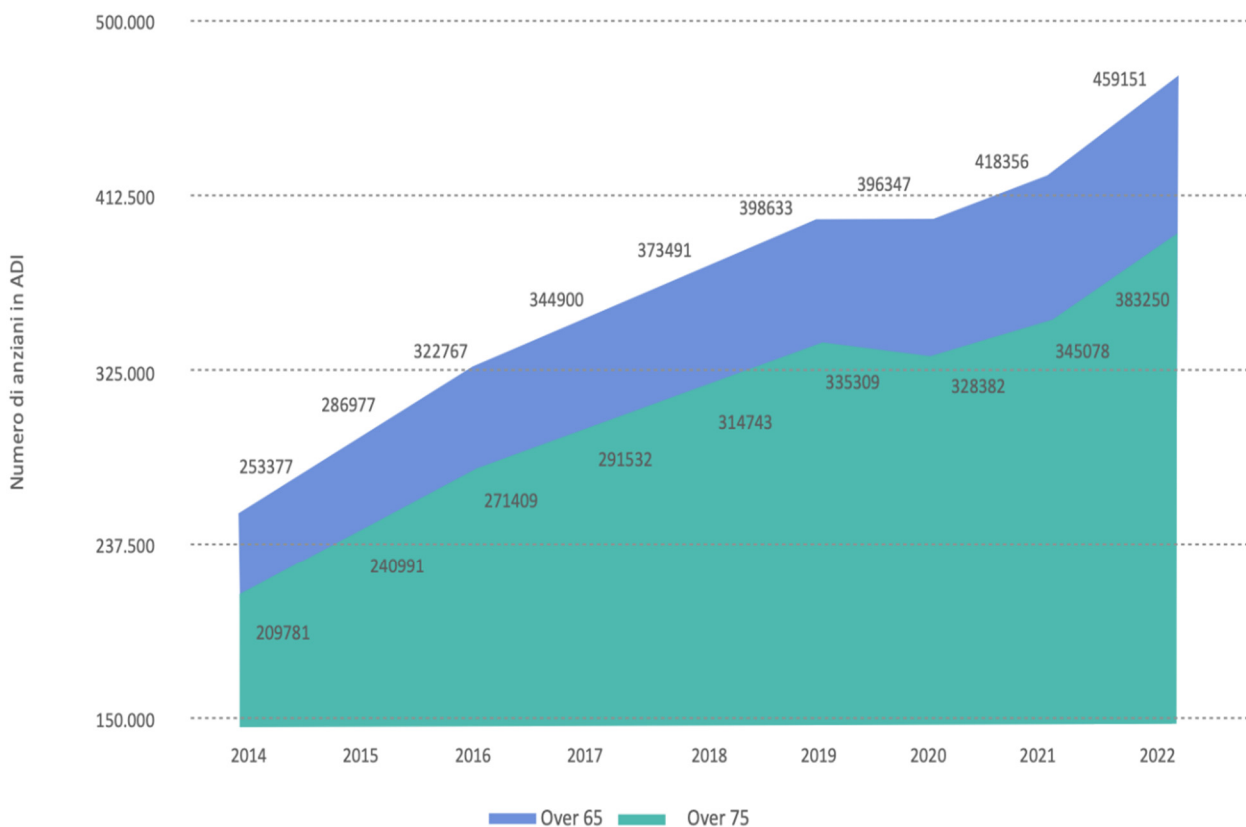


Fig. 1 Number of elderly people assisted by Integrated Home Care / Reworked by the author from Indagine 2023 Italia Longeva.

The home, unlike the other spaces that we inhabit at various scales is the very projection of the personality of those who live in it, as "living" is a complex way of interacting with the space that involves people and space, both active subjects, through a plurality of elementary factors consisting of gestural and non-gestural actions by the inhabitants on the elements of the inhabited space. This intimate ritual, as an expression of one's culture and as a compliant response to expressed needs, is a variable process that can lead to conditions of maladaptation with respect to a system of needs that evolves and changes with advancing age - associated with a loss of ability that affects independence and autonomy - modifying the "sense of familiarity" that that same system expressed.

This lasting bond of affection with one's home acquires greater significance in Italy, where the political-economic strategies of the classes that have taken turns in power and the anthropological and

cultural characteristics have - the former - progressively induced Italian families to identify the home of property as a form of investment, leading to a very high share of home ownership compared to the European average [2] and - the latter - to weaving living in a stable and rooted way into a territory of social and neighborhood relationships that play a central role on the risk of isolation and loneliness in the elderly population (Fig.2).

The perpetuation of these profitable identity, economic and social conditions is strictly dependent on the ability of the home to adapt to the physical changes of its inhabitants, intercepting even the most extreme conditions of coexistence of the living space with care activities, maximizing the stay in one's home in conditions of safety, autonomy and independence and consequently burdening the healthcare system as little as possible.

A necessary and fundamental bond between healthcare models and housing models whose advantages have

long been reflected in Evidence Based Design³ already called for by Law no. 833/78 but poorly applied. This bond seems to have reached the urgency of concrete implementation thanks to the resources made available by the National Recovery and Resilience Plan which – among the various measures to modernize the organization of care – provides for strengthening of assistance within private homes. However, the centrality of the topic corresponds to a confusing literature: one need only think of the different terms used today to indicate home healthcare (Hospital in the home, Home Healthcare, Home Hospitalization, Early Supported Discharge) and the different types of services provided: some of them focus on specificities (surgical and rehabilitation medicine, geriatrics, psychiatry, infectious and respiratory diseases), and others on diagnostic groups or a combination

thereof [3, 4].

Among the actions to promote aging in place, adaptability solutions for the domestic space and its equipment and their integration with enabling technologies constitute a possible strategy to satisfy the particular needs of elderly people. The research presented here – part of an ongoing study on the complexity of the relationships between people and the characteristics of the space/equipment system – aims to contribute to considering aging a structural condition to be foreseen in every design action, not as a possible option but as an opportunity to design spaces and equipment adaptable to elderly users and their varied abilities/disabilities, including the unavoidable challenge of the digital transition in the formulation of alternative types of intervention.



Fig. 2 Photo by Kaspars Eglitis.

³ The studies available in the literature show that Healthcare at Home guarantees greater conditions of well-being, safety and autonomy for frail elderly people who receive assistance in a familiar and reassuring environment (NRC, 2011; Covinsky,

2003) and reduces costs and stresses on saturated healthcare facilities, including emergency departments and hospitals with limited bed capacity (Cohn, 2022).

2. Home-Based Care: Between the Specifics of the User and the High-Performance Space

Home-Based Care includes admission avoidance (i.e. full substitution for hospitalisation) and early discharge followed by care at home (i.e. shortened hospitalisation). It can be cost-effective and convenient, reducing unnecessary hospital admissions and allowing patients to receive the care they need where they are most comfortable [5]. The advantages of Home-Based Care can be summarized in the following ways:

- greater safety for frail elders because they will have fewer of the common complications of hospitalization (such as delirium, stress etc.). The NRC report [6] noted that acutely ill older persons often experience adverse events when cared in the acute care hospital, while they value the delivery of health care at home, as it promotes healthy living and well-being when it is managed well. Living independently at home is a priority for many, especially individuals who are ageing with a disability;
- greater patient-centred care [7], that leads to a better understanding of important issues, such as how medications and nutrition are handled, a more intimate clinician-patient relationship;
- greater patient autonomy [8], especially patients with lower levels of mobility and elders can benefit from the opportunity to receive the care they need where they are most comfortable.
- lower costs [7, 9] and lower strain on saturated healthcare facilities (including emergency departments and hospitals with limited bed capacity) [10]. Besides, Home Healthcare can reduce unnecessary hospitalization and connected risk of healthcare-associated infections [10, 11].

While there are numerous advantages to Healthcare at Home, there also are many challenges. There are still only a few healthcare organizations that offer formal home-care models for primary and hospital-level care (e.g. Johns Hopkins Hospital at Home, Ohio Veterans

Administration Hospital in Home) and there are limited researches available on the role of the built environment in safe and effective delivery of healthcare at home, for both patients and providers (Universal Design, Aging in Place, Healthcare at Home approaches). However, as Healthcare at Home is becoming more commonplace as a practice, there is an opportunity to shift thinking from the typical residential design to a more sustainable home concept, ‘how the home can support health and healing’. This has led the medical community to seek to provide more tools and methods of care that patients can safely access right from home, and the designers to think as the homes of the future will need to be laid out strategically to address both an array of ageing needs and support this form of healthcare delivery.

3. Objective and Subjective Qualities in the Home Adaptation Process

The framework of changes and renewed needs – including the COVID-19 pandemic, which increased the variability of home use in response to health needs – has been an impetus for the development of new housing models. However, it is also necessary to intervene in existing housing both to improve the stay of the elderly at home in conditions of sufficient personal independence, and to accommodate, when the need arises, the activities of Healthcare at Home while maintaining the maintenance of identity and self-esteem [12, 13]. This adaptation process, within the limits of pre-existing environmental constraints (functionality and sizing of spaces) and technological ones (structures, partitions, etc.), will have to go beyond the removal of architectural barriers, aiming to enhance the “stress-reducing” factors and reduce the “stress-inducing” ones deriving from multifactorial qualities of the space: physical, environmental, managerial, perceptive, psychological and relational elements, from a perspective that is not “patient-centered” but considers the totality of the users involved (assisted person, family members/caregivers, medical/nursing staff).

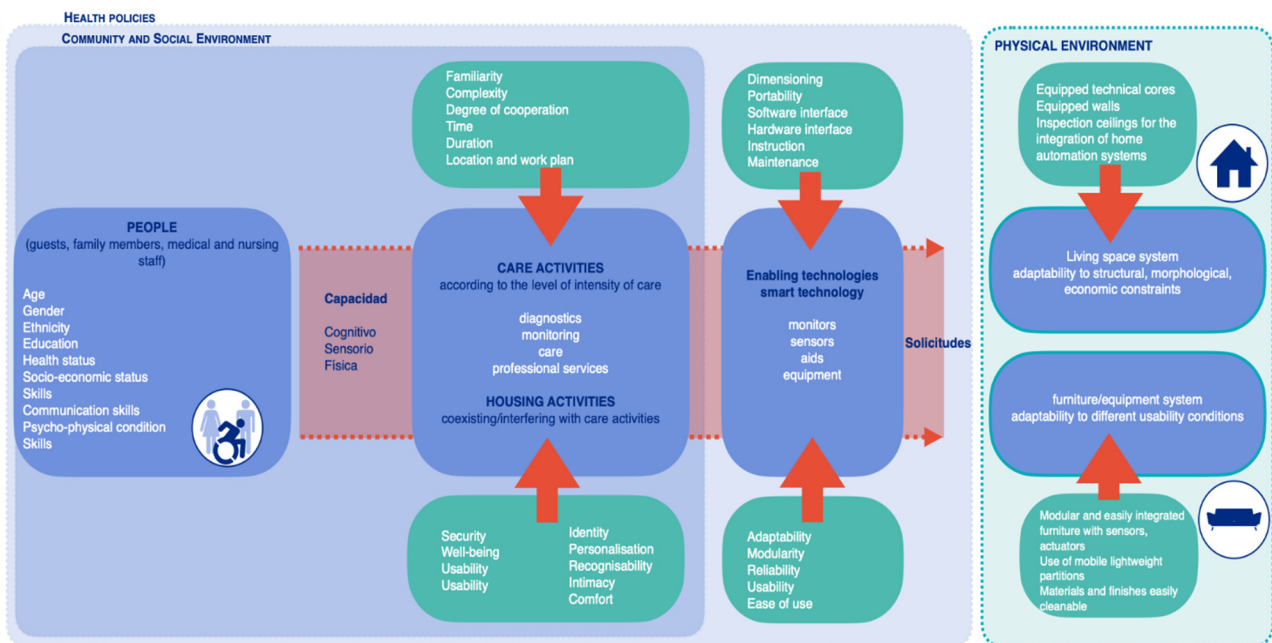


Fig. 3 Process of adaptability of the home to care.

In this paper the more general objective of innovation of the home environment for elderly people is specifically oriented towards a reflection on the interaction between person-furnishing system-home environment, in which the quality of the solutions is conveyed by the correct correspondence between people, activities, physical environment and the range of equipment/technologies that can facilitate the usability of the space/furnishing system and make-up for any loss of skills.

On the one hand, these interactions can be physical through the search for dimensional, material and sensorial relationships with which to control the coherence and appropriateness of the inputs by the artefacts to the physiological structures of individuals. On the other hand, they can be filtered by highly technological devices (sensors, actuators) capable of weighting these inputs with respect to the individual characteristics of possible users (Fig. 3).

Consequently, the research has explored the theme of the definition of a methodological approach to the adaptability of the domestic environment with respect to the needs of the users involved and to two “spatial elements” in which the maximum complexity of the

design choices and the maximum request for the adaptability of the domestic space is manifested: the bedroom and the bathroom.

The scarcity of applied research and evidence-based studies capable of defining the characteristics of a living space so that it is suitable for care conditions has led to the need to delve into the studies available on spaces that present similar demands for evolution and adaptivity of the space-furnishing system in order to respond to the bio-psychosocial needs of users (hospital wards, bedrooms in nursing homes) and to integrate them with the needs of a “qualitative” nature (subjective, psychological), with the need for personalization of the living space (customization of furnishings) and with the opportunities offered by the implementation of new biomedical and digital technologies, showing the impact that some innovations can have in terms of resilience.

4. The Patient Room as a Model for Investigation

There is a paucity of literature on the adaptation and design of the home environment for the future health care needs of the owner in their own home, in order to

facilitate and enable the best implementation of these needs. Consequently, the research examined 'hospital rooms' as case studies, which represent the closest and most similar environments to those in the home and allow a better understanding of the composition of care spaces and the needs of the different users involved in the care process (Fig. 4).

Over the last ten years, technological progress in healthcare management and communication systems (telemedicine), the gradual replacement of the human factor through robotization (automation of care work) and digitization (magnetic resonance, CT and PET scans) have led to a reorganization of hospital facilities – and the 'patient rooms' – so that they can

accommodate the changes taking place in a fruitful relationship between:

- user-centred approach that has influenced not only the modes of communicative exchange between patient and medical staff but also the physical-functional characteristics (accessibility, distribution of spaces) and the psycho-sensory and perceptive characteristics of care spaces finding confirmation in Evidence-Based Design;
- bio-technological approach that has led to a further reorganization of hospital structures and to the emergence of new, highly original and relevant forms of interaction aimed at the 'medicalization of life'.

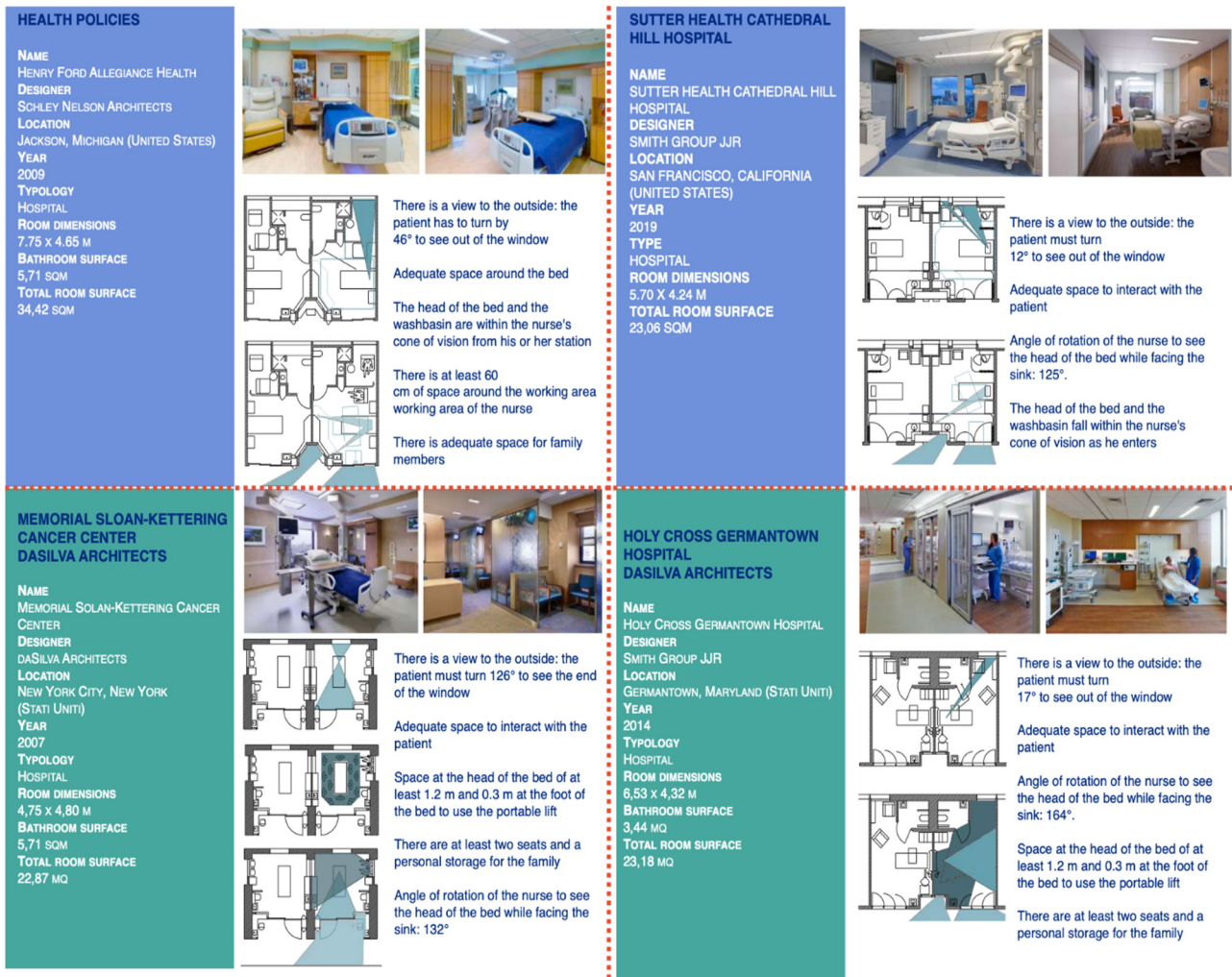


Fig. 4 Comparative analysis of hospital rooms designed according to criteria of humanization of space and efficiency of care.

This approach applied to home care involves extensive reflection on the following issues:

- Spaces for privacy/intimacy. Although the patient's room (which in a house corresponds to the bedroom) must respond to the needs of process efficiency and effectiveness of care, it cannot be neglected in a broader vision of health as psycho-physical well-being, with attention to characterization – for volumes, materials, colors – of spaces (New Children's Hospital in Finland, GAPS psychiatric hospital in Denmark) and personalization/appropriation of spaces for intimacy/privacy (the transformability of the wards in the Meyer Pediatric Hospital in Florence and in the Agatharied in Germany). This condition can be achieved through a spatial/functional organization of the room to avoid visibility of the care areas from the common areas or through movable partitions and glass doors that can be darkened;

- Environmentally responsible materials. Another front is that of innovation in the field of building materials in which the frontiers of technological innovation focus on the possibility of having antibacterial and antiviral but also sustainable materials, free of toxic chemicals in order to improve internal air quality and reduce impacts on public health.

- Family-friendly spaces. The presence in the hospital room of a specific area intended to accommodate family members – including seating and possibly beds added – allows active involvement of family members in certain aspects of care as well as in psycho-physical support for the patient, with positive effects on clinical outcomes. Even within the patient care bedroom, it is important to consider a space where a possible family member can comfortably stay with the patient.

- Nursing/caregiver stations. Implementation of flexible solutions for adapting the patient's room to the levels of care also involves new solutions for the position of the nursing station (which includes spaces for documentation, drug storage, nursing supplies, equipment, etc.). The nurse must be able to carry out

his or her activities, such as preparing for treatment, undisturbed and with a direct view of the patient.

- The integration of ceiling-mounted patient lifts. It can be useful to reduce staff back injuries caused by lifting patients in and out of bed or a bathroom, staff sick time, and hospital costs. The integration of the lift rails in the ceiling, hiding them from view, contributes to a more discreet and less hospitalised home environment.

In relation to these macro-interventions, criteria for the adaptability of the home to care were developed and incorporated into an agile verification tool that combines interventions on the 'space system' and the 'equipment system' with integrable intelligent technological solutions that can support the various actors in the care process (patient, nurses, carers, family members).

5. An Adaptability Support Tool

A first result concerns the development of a tool for verifying the adaptability of the space/furnishing system to the main activities of the users involved classified with respect to requirements of a quantitative nature (ergonomic, functional and technical) and of a qualitative nature (personalization, conditions of psychophysical well-being) to be satisfied, deduced from studies carried out on the subject of adaptation of "spatial elements" (bedroom and bathroom) – indicated in the previous section – and weighed up with respect to the contextual factors of the living space and clinical aspects of the patient.

Placing the person at the center of the adaptation process arises from a rejection of "medicalization" of space and objects, for which the simple possibility of hosting certain care activities within the home does not entail achievement of an adequate level of adaptability of the space-furnishing system, seen as a balanced expression of the process of adaptation to the changes that have occurred in the life of the subject and his or her family through efficiency of care and humanization of environments, furnishings and aids.

For this reason, the second result of the research concerns the development of a framework of possible project strategies for adaptability of the living space and integration of technological systems (Ai, ICT, smart devices, Ambient Assisted Living technologies) which can facilitate patients in carrying out daily activities and medical/nursing staff in carrying out/monitoring treatments.

The tool for verifying the adaptability of the space/furnishing system to the care conditions is configured as a tool for prefiguration/generation and evaluation of design alternatives, structured according to a “what if” (or if-then) analysis procedure that identifies (through classification of problems) potential critical situations and preventively ensures “soft” solutions (minimally invasive) or “hard” ones if the “soft” solutions are insufficient.

The former concerns integration of elements, components and furnishing systems and/or smart technologies already in production for customization of spaces/equipment to reduce the intensity of the consequences relating to that critical condition, while

the latter concern “tailor-made” personalized solutions – deriving from observation activities, measurement of residual skills and monitoring – capable of compensating for progressive loss of physical-motor skills through the enabling effects induced by the variable performance capabilities of elements, equipment and spaces and their integration with enabling technologies.

Preliminary verification of the minimum geometric, dimensional and plant engineering conditions for the adaptability of accommodation is followed by identification of possible group design strategies of two areas of application: the scale of the object/equipment, and the scale of the built space (Figs.5 and 6).

At the object/equipment scale, adaptability takes the form of replacement/integration of furnishing systems that facilitate management of future transformations through modularity and interchangeability of components and customization of features and accessories. These customized systems, if associated with a careful analysis of the user’s gestures in carrying out the activities – to intercept the solutions adopted to reach the objective,

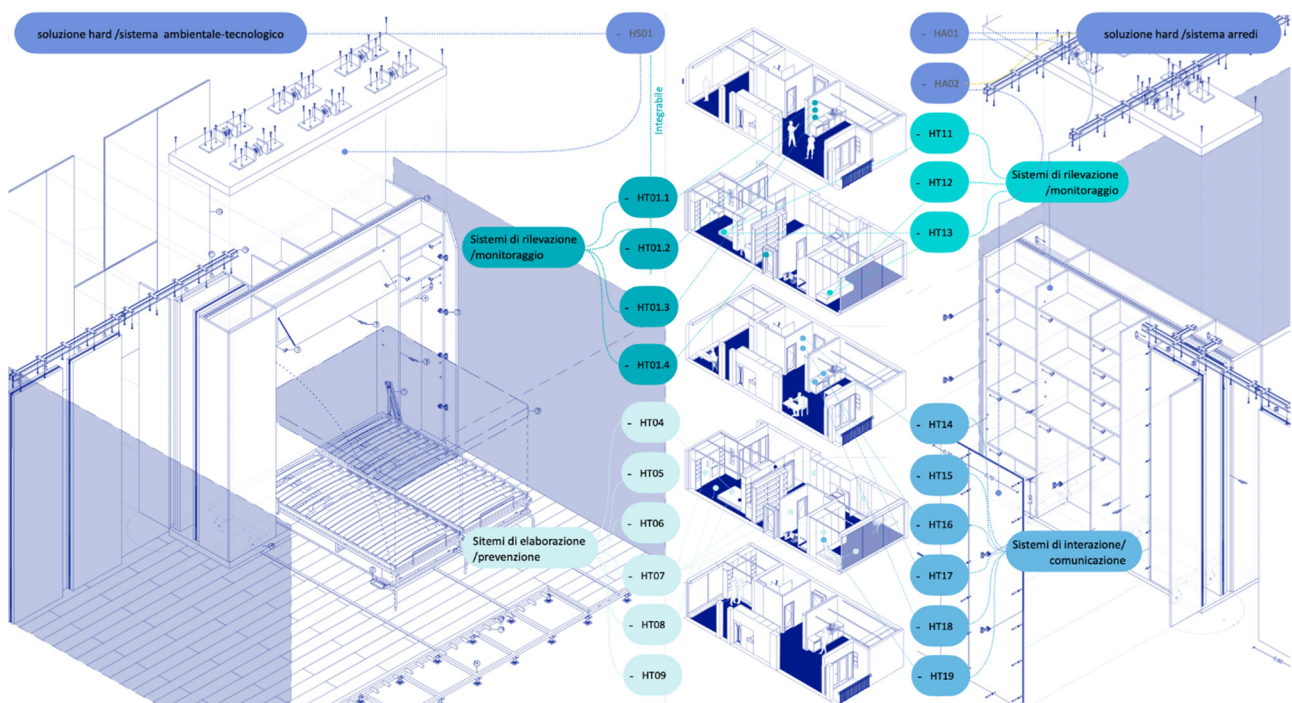


Fig. 5 Exemplification of the adaptability tool with respect to some requirements characterizing the spatial element “bedroom”.

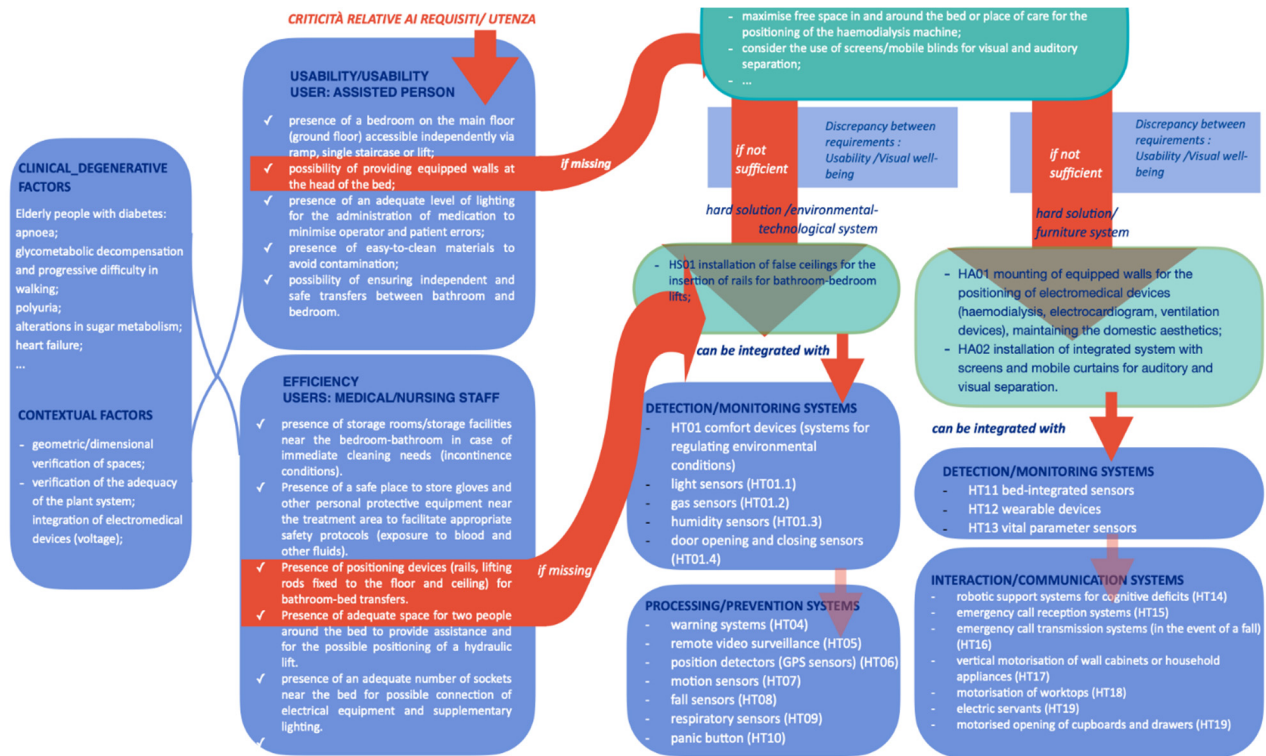


Fig. 6 Home healthcare model.

with other capabilities (physical and communicative) and other resources (technical and spatial) – make it possible to have another level of flexibility of the equipment or component, dedicated to the individual specificities/ skills of the user. It follows that even evaluation of a single action necessary to carry out an activity (push/pull, lift/lower, open/close) or the design characterization of a technical-constructive element (smooth/rough, devices for pressing/touching) is configured as fundamental to provide solutions that can be adapted to contingent needs and requirements, to support greater independence of assisted patients and facilitate the work of home healthcare workers (Figs. 7 and 8).

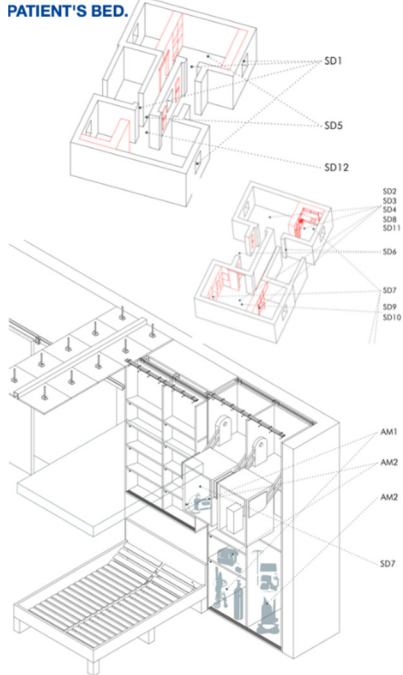
A further performance upgrade can be obtained by integrating monitoring sensors that can be integrated into wearable devices/objects capable of collecting diagnostic data (e.g. data on posture, physical activity, habits) in order to monitor health conditions of elderly people and interactions capable of supporting the residual abilities of users (vertical motorization of wall cupboards and worktops) as well as interacting with the end user (e.g. devices that remind the user to take drugs

or a certain therapy) and with the outside (e.g. motion sensors that alert the user who moves away beyond a certain radius from the action) as they are connected to outdoor systems.

At the scale of the physical space, adaptability is applicable in design strategies capable of facilitating care and assistance tasks (equipped walls/attics, technical nuclei that can be integrated with plant/electromedical equipment functional at different levels of care); of improving the conditions of psychophysical well-being, accessibility and safety for patients and operators (reorganization of the distribution system based on new ergonomic needs, monitoring of indoor conditions, mobile dividers for the patient’s privacy during treatment); of guaranteeing customization of space through the study of its ergonomic optimization to the specific needs of the user.

A further performance upgrade can be obtained by integrating sensors: monitoring devices that can be integrated into wearable devices/objects capable of collecting diagnostic data (e.g. data on posture, physical activity, habits) in order to monitor the health

INTEGRATION OF HOME AUTOMATION SYSTEM AND MEDICAL EQUIPMENT IN AN EQUIPPED WALL BEHIND THE PATIENT'S BED.



HOME AUTOMATION SYSTEM

SD1 - Opening and closing doors
Possibility of automating the opening and closing of doors, gates, awnings, shutters and the like

SD2 - Alarm systems
Both visual and audible alarm systems to detect the presence of smoke or flooding, gas/methane leaks, closing solenoid valves

SD3 - Lighting
Lighting control of all rooms. Possibility of switching on, switching off, regulating switching

SD4 - Temperature control
Temperature sensors for regulating air conditioning, heating ventilation

SD5 - Current load control
Ability to monitor and manage current loads with a view to saving energy and preventing overload blackouts.

SD6 - Security/video surveillance and video telephony
Cameras and intrusion detection systems on doors and windows for real-time monitoring.
Possibility of communicating with the outside of the house or making calls intercom calls from one room to another

SD7 - Control of household appliances
Automation systems for setting, programming and remote control of electrical appliances, internal sliding doors, furniture (motorised doors)

SD8 - Fall prevention sensors
Monitoring sensors to prevent falls in elderly people, especially in bed-ridden persons

MEDICAL EQUIPMENT

AM1
Blood gas/ pH/ chemical point analyser
Dimensions (mm): 100 x 300 x 400, Weight (kg): 1-5
Electrocardiograph
Dimensions (mm): 120 x 400 x 350, Weight (kg): 6
Haematology analyser
Dimensions (mm): 100 x 300 x 400, Weight (kg): 1-5
Portable ventilator
Dimensions (mm): 150 x 250 x 300, Weight (kg): 7
Air purifier
Dimensions (mm): 240 x 240 x 520, Weight (kg): 2.5-5.5
Transcutaneous blood gas meter
Dimensions (mm): 100 x 300 x 200, Weight (kg): 0.5-5
Oxygen cylinder
Dimensions (mm): 700 x 110, Weight (kg): n.s.

AM2
Cardiorespiratory monitor (apnoea monitor)
Dimensions (mm): 150 x 120 x 120, Weight (kg): 0.75
Cardiorespiratory monitor (apnoea monitor)
Dimensions (mm): 150 x 120 x 120, Weight (kg): 0.75
Blood pressure monitor
Dimensions (mm): 100 x 150 x 200, Weight (kg): 3
Defibrillators
Dimensions (mm): 100 x 250 x 200, Weight (kg): 2.5
Glucose meter
Dimensions (mm): 90 x 50 x 100, Weight (kg): 0.65

AM3
Aspirator
Dimensions (mm): 300 x 400 x 800, Weight (kg): 5-25
Crutch
Dimensions (mm): 90 x 950, Weight (kg): n.s.
Haemodialysis unit
Dimensions (mm): 1380 x 450 x 500, Weight (kg): 85

Fig. 7 Integration of devices and smart technologies.

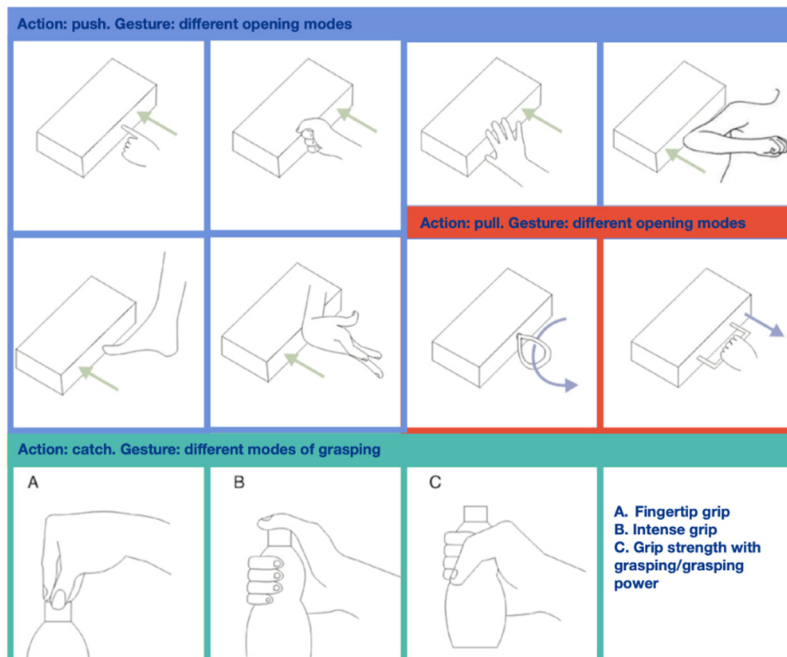


Fig. 8 Different user-furniture interface scenarios according to each person's abilities.

conditions of elderly people; of interaction capable of supporting the residual abilities of users (vertical motorization of wall cupboards and worktops) as well as interacting with the end user (e.g. devices that

remind the user to take drugs or a certain therapy) and with the outside (e.g. motion sensors that alert the user who moves away beyond a certain radius from the action) as they are connected to outdoor systems.

6. Conclusions

The solutions and alternatives analyzed show that the physical environment can lead to positive results in terms of well-being (for users and operators); staff productivity (workflow); clinical safety (prevention of medical errors, incorrect application of therapy, contraction of nosocomial infection), psychological and physical safety, (prevention of medical errors, application of therapy, contraction of nosocomial infection and reduction of stress factors). However, adaptability of the home to meet these new needs clashes with the limits relating to the structural and typological constraints of existing housing, which constitute the main barrier to adaptation to new organizational/spatial models. However, if the home is not properly equipped, or if a formal home-care model for hospital-level care is not available, hospitalization or a move into a rehabilitation or long-term care setting may be the only viable option for people with increasing healthcare needs [14].

There is also a problem of a psychological-behavioral nature due to the stressful conditions to which the medical-nursing staff will be subjected who find themselves working in new spatial models, with repercussions on tasks, duties, and workflows/habits. Precisely this complementarity between design actions aimed at guaranteeing the well-being of the users involved and organizational actions aimed at optimizing care suggests promising research spaces that can be investigated, further developed and possibly tested in real empirical contexts, through involvement of figures belonging to different scientific disciplinary sectors.

Furthermore, the majority of the literature refers to individuals receiving care at home as “patients”. However, the individuals receiving care may or may not see themselves as patients in their own homes. This is an important distinction in how care is provided and designed. Healthcare at Home does not involve just a functional dimension, but also an emotional one (sense of comfort and safety, based on familiarity and/or

memory). For these reasons, other limits to the application of this model concern:

- the degree of adaptability of dwellings both to the evolving needs of its residents and to the evolution of the disease;
- the high costs of upgrading and adapting, the high upgrade and adaptation costs, which could be avoided, especially in new constructions, through a design that considers the user and his needs as they evolve over time.

Continental and Nord Countries are moving in this direction both with guidelines for the low-cost adaptability of the existing and new housing stock [15] and with financial schemes for the adaptation of housing to the individual limitations of the people.

Multidisciplinary equips (formed by owners, architects and designers in healthcare) may be the best qualified to undertake the challenge of design for Healthcare at Home. They aim to balance the provisions for safety with the preservation of the personal effects and person-centred experience that make healthcare at home such an attractive option for healing in the first place.

Therefore, the validity of a project can be appreciated by the multifactorial quality of the space. It can be connected with physical, environmental, management, perceptual, psychological and relational elements, in a perspective that is not “patient-centric” but considers the totality of users.

However, the future research spaces in this field are large, and the possible scenarios of use concern the development of tools for verifying the adaptability of the homes; for guidelines, useful for public administrations in drafting innovative tenders for the construction of new social housing or senior housing, also through the use of simulation systems (Digital Twin) capable of verifying the possible transformation scenarios with the impacts on staff productivity, on the patient safety and well-being and on accessibility to treatment.

In conclusion, the relationships between the domains analyzed (users, activities, smart technologies) – aimed

at improving with respect to the tangible and intangible dimensions of an environment – and the scenario-setting of intervention alternatives constitute an innovative research area in an emerging market segment, that of the so-called Silver Economy, in which there are well-defined questions which do not have clear and decisive answers but ones that are often dictated by a condition of provisionality and emergency.

Precisely the synergy between the research and development sector and the production sector can contribute to the development of a new industry capable of generating social value through production of innovative components for adaptation of housing units and the improvement of innovative assistance services by cooperatives and public and/or private companies.

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