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BIM AND IOT FOR AAL
Digital modelling and 4.0 management for care and assistance services

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ABSTRACT
The transition towards digital healthcare is considered by the EU as a successful approach to improve assistance access and care quality and to increase the efficiency of the healthcare system. The use of BIM, IoT technologies and ICT applications in the Architectural Engineering and Construction Industry (AEC) can provide important benefits to the implementation of effective design and management processes, revolutionising the design of buildings used to provide care and assistance services. Starting from the comparison with some design experimentation experiences carried out during the pandemic, this paper deals with the development of a digital model of Ambient Assisted Living (AAL) where the BIM method is used to facilitate the interoperability of the data concerning IoT devices and the management of Facility Management activities linked to it.

KEYWORDS
ambient assisted living, building information modelling, healthcare design and management, internet of things, industry 4.0

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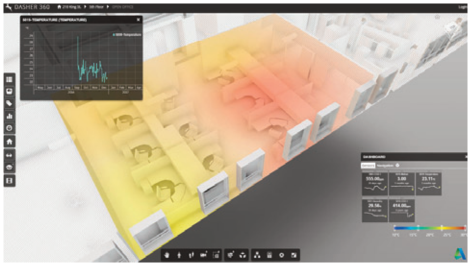
The transition towards digital healthcare is considered by the EU recent funding programs and research projects[1] as a successful approach to improve healthcare access and quality and increase the efficiency of the healthcare system (European Commission, 2021). Digital technologies are an effective solution to overcome the post-pandemic Covid-19[2] crisis, allowing significant economic savings on public expenditure and helping to address social and health challenges related to the fragile and ageing population (European Commission, 2020). Facing this transformation, the most physically and economically fragile people could benefit from many advantages linked to 'digital health', such as better access to services and a quick response to the need for care and assistance.

The pandemic has led to a progressive acceleration of the digital processes, requiring a need to invest and innovate, within a consistent and structured development Plan, to quickly make up for a years-long – at least in Italy – delay. The modernisation and redesign of hospitals and care facilities are necessary for outdated buildings, technology and electromedical equipment (Arbizzani, 2021). It is part of a greater economic and social recovery plan, involving different sectors. The implementation of financial tools for the recovery after the pandemic – as the Next Generation EU[3] in Europe and the PNRR (National Recovery and Resilience Plan)[4] in Italy – encourages the development of structural and precise interventions on the existing building heritage and the creation of new buildings, useful to boost the healthcare network. It also envisaged the reconfiguration of spaces to accommodate new equipment and technological devices to facilitate the provision of advanced health and assistance services aimed at fragile users, particularly people with impairments and the elderly.

Implementing the use of state-of-the-art plant equipment and digital technologies in buildings is as important as implementing multidisciplinary integrated design methods and tools, involving more workers with different skills within the same industry, with the aim of reaching a higher quality in the whole building process (Arbizzani and Clemente, 2020). The use of BIM (Building Information Modelling) methodology could give a strong boost to the creation of complex buildings and management of advanced services, representing a shared tool capable of managing building processes (Russo Ermolli, 2018) with highly informative content.[5]

The focus on some experimental design experiences carried out during the pandemic shows the need to accelerate this evolution, depending on environmental and technological factors that could influence the speed of construction with shared project operations. The results of these experiments show the use and effectiveness of the BIM tools during planning and building in emergency conditions. One of the most innovative and potentially promising aspects is the possibility to control the whole design process with the use of informed modelling methodologies and the development of interoperable platforms. The maturity reached by the IoT (Internet of Things) technology of exchanging data between commonly used objects, together with the ICT (Information and Communication Technologies) platforms and the BIM tools of syn-

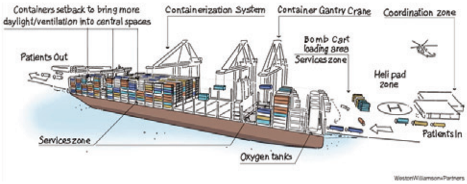


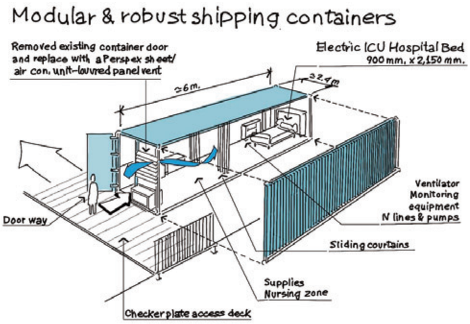
Figg. 1, 2 | The DASHER project by Autodesk links the BIM model to IoT technologies. The sensors located in the environment allow monitoring of a building's performance, including lighting, the movement of dwellers, and the level of carbon dioxide in the environment. Navigate in the BIM model through an ICT platform allows accessing data monitored by IoT devices, making certain specific conditions in the environment, such as temperature, or the path of dwellers, immediately visible (source: autodeskresearch.typepad.com; dasher360.com).

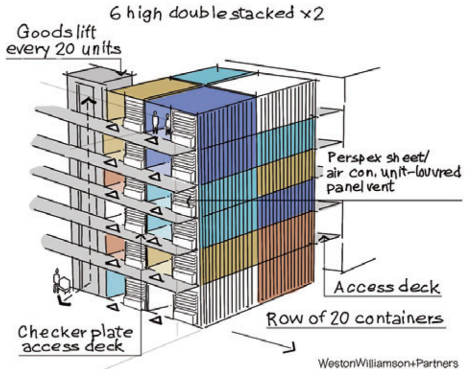
chronising pieces of information coming from different sources (Tang et alii, 2019) can allow to experiment innovative methodologies to supervise the project (Figg. 1, 2), and enabling innovative digital services for care and assistance and related Facility Management activities.

In this context, the paper deals with the development of an AAL (Ambient Assisted Living) for fragile users, where the digital representation is used as a tool to ease project management and interoperability of the data concerning a range of IoT devices placed in the environment. Through the modelling of four housing units for the elderly and the creation of a data-set of parameters and attributes associated with IoT sensor technologies, a structured model of digital facilities was defined. The logic of relational databases, interoperability and informative enrichment was used as an effective device to trace heterogeneous data, envisaging the accessibility to information through a web services platform and the replicability and extension of the BIM model and different use contexts. The innovative and original aspect of research is the experimentation with innovative ways to define the project and to handle details through the implementation of categories, objects, parameters and features belonging to AAL components for care and health, traditionally not planned by default BIM models.

Pandemic Emergency, Architecture for Health and Digital Innovation | Faced with the quick and uncontrolled growth of patients with severe respiratory syndromes, hospitals had considerable difficulties to adapt the number of intensive care units to the unforeseen necessity dictated by the pandemic. The health Emergency has required, in particular in the first stage, the creation of emergency hospitals with tents and temporary set-ups – not always effective for the safety of health workers – then replaced with the construction of new wards or the renovation of existing ones. In some countries, compounds were made with containers equipped with tools necessary to care and assist and bio-containment systems to ensure maximum protection against any outdoor con-





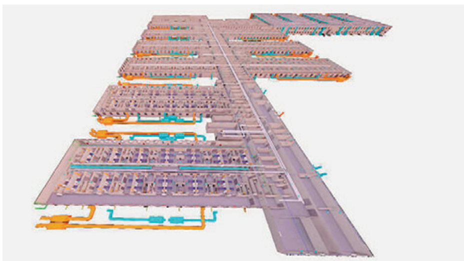


Figg. 3-7 | The Weston Williamson + Partners project represents a visionary study on how container ships could be transformed into huge hospitals and reach by water the cities mainly affected by Coronavirus, in particular those with less access to healthcare. With about 2000 beds, each container is a modular intensive care unit (credit: Weston Williamson + Partners, source: dezeen.com).

tact. At the international and national scale, guidelines were created (WHO, 2020) and project experiments were undertaken (Figg. 3-7) aimed at sustaining the main need to limit in a short period and through architecture, the health emergency.

Wuhan Huoshenshan Hospital is a temporary structure made in the epicentre city of the pandemic, on an area of approximately 34,000 square metres, designed in just 24 hours and built in about 10 days, to treat patients infected with Coronavirus (Fig. 8). The hospital, with about a thousand beds, has two levels, made with off-site modular units of reinforced concrete and steel structural supports. The containers have spaces for intensive unit care and hygienic facilities, with finishes that guarantee healthy, cleanable and durable conditions, while medical equipment cables are concealed in internal partitions. The use of the BIM method (Fig. 9) has allowed, from the conceptual phase up to the building stage, the shared participation in the project choices by stakeholders (such as government and municipal representatives) and a multidisciplinary work team (such as designers, doctors, nurses and workers, etc.) that took care of the coordination of the work (Peng, 2021). The digital BIM representation was effective to create a modular design, useful for standard production and manufacturing of off-site components, and the real-time visualization of the project, allowing shared controllability of the model and its parts in the design stage and limiting possible mistakes in the building stage, with reduced building site deadlines (Fig. 10).

The Leishenshan Hospital was created in the Jiangxia district in Wuhan, a space of approximately 220,000 square metres for a total construction area of almost 80,000 square metres (Fig. 11). The hospital is divided into three functional areas, organized in dirty-clean paths: the living area for the medical staff; the logistic area for the decontamination of ambulances and waste and wastewater treatment; the space destined to medical care (Figg. 12, 13). The project was organised based on modularity: the off-site unit (with standard dimensions of 6.0 x 3.0 x 2.6 m or 6.0 x 2.0 x 2.6 m) was made by an isolation room (equipped with all the necessary medical and plant engineering equipment) and a bathroom that becomes a filter between the two transit areas for doctors and patients (Figg. 14, 15). The model of the building was defined by the BIM methodology (Ling-Kun et alii, 2021), and has allowed, in the design stage and during construction, to control and achieve optimal performance standards (Figg. 16, 17). For the Leishenshan Hospital, the use of BIM tools was useful not only to save as much time as possible, but also to simulate space ventilation, and hence to foresee the possible airborne transmission (Fig. 18) during operation stages.



Figg. 8, 9 | Wuhan Huoshenshan Hospital is the world's first large-scale temporary facility built in record time to accommodate people infected with Covid-19. Designed in 24 hours with BIM methodology and created by CITIC Architectural Design Institute and China Construction Third Engineering Bureau, by a team of approximately one thousand five hundred workers and five hundred construction machines, at the request of the Wuhan municipal construction unit (source: redshift.autodesk.it; credit: CITIC ADI).

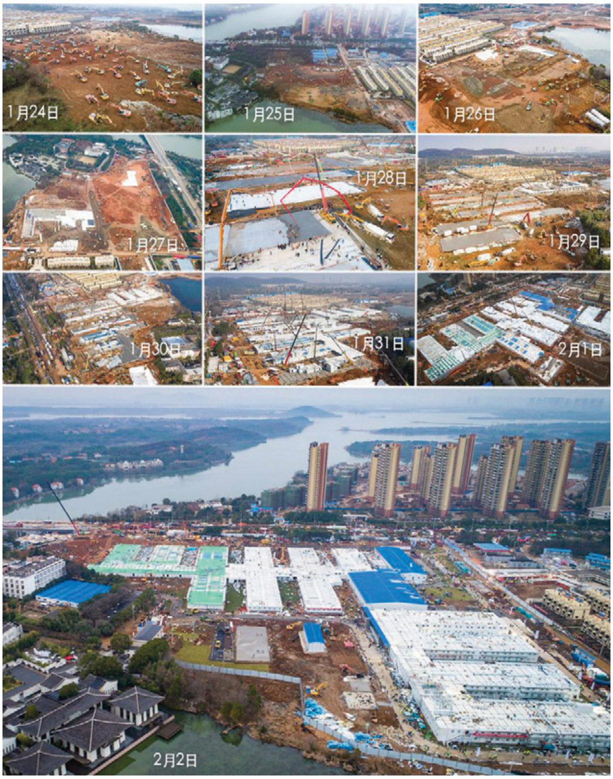
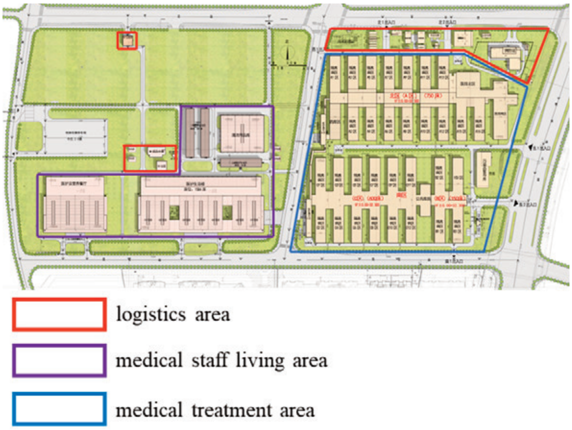
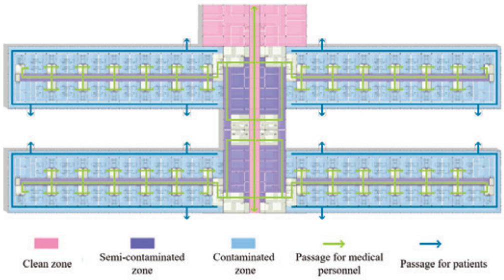


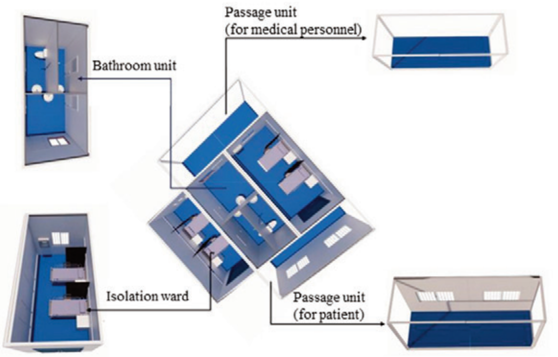
Fig. 10 | Building site stages of the Huoshenshan Hospital in Wuhan, built in 10 days (source: mfa.gov.cn).

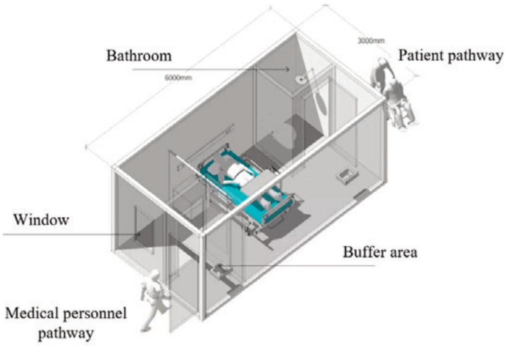
Fig. 11 | Global view of off-site modular units in the Wuhan Leishenshan Hospital project (source: archdaily.com).

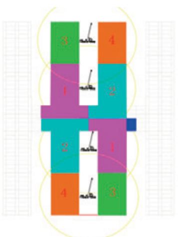
The CURA Pods project (Connected Units for Respiratory Aliments) was created by an international group of practitioners (architects, engineers, doctors, nurses, etc.) led by the architect Carlo Ratti, as a temporary module to handle intensive care resulting from Covid-19 infection (Fig. 19). The model is a container (2.44 x 6.05 x 2.59 metres in height) combinable and transportable. The container was made of aluminium composite panels consisting of two sheets with a polystyrene core, with a negative pressure bio-containment and an extractor filtering the air to avoid external contamination. Through two glass windows, the healthcare workers, and families, can watch the patients. The off-site modules can be assembled with inflatable corridors (3.00 metres in depth x 3.20 metres high), used as warehouse and dressing room, capable to take on multiple configurations that can be extended as needed, from 4 to 40 beds (Figg. 20-25). The model was developed with an ‘open source’ methodology with the cooperation of an international task force[6], made up of many international professionals, each one with their knowledge, has helped to set technical specifications and project requirements. The architectonic representation of the base module, with equipment, furnishings and facilities, was made with the BIM software Edificius® (Fig. 26). It produced a three-dimensional digital model of a hospital intensive care unit also to be used as a data container or ‘digital

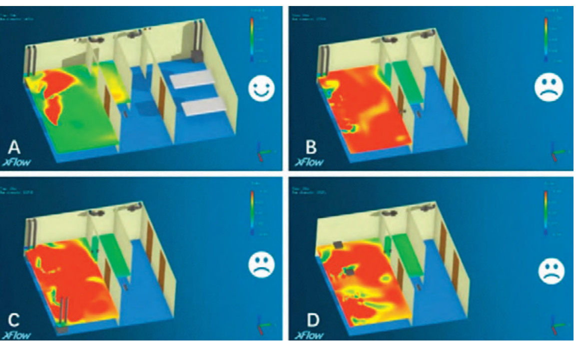












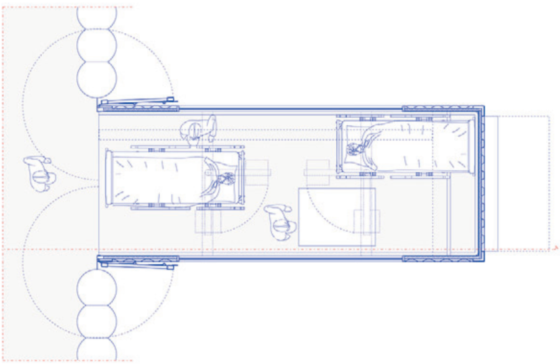
Figg. 12-18 | Functional layout and BIM model of the Leishenshan Hospital in Wuhan were created also to simulate and prevent viral contamination in modular units (source: sincedirect.com; credit: CITIC ADI).

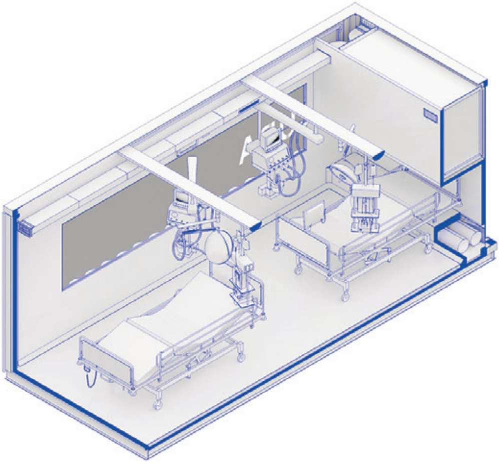
Fig. 19 | Scenario of insertion of the CURAPods project in Milan, urban context (source: archipanic.com).

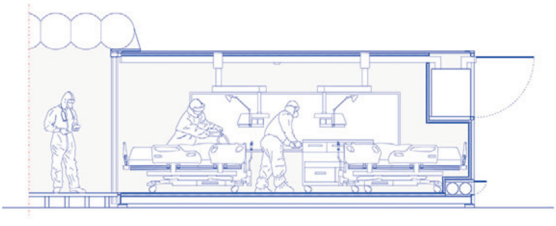
twin'[7], capable of carrying out any simulations to be applied to the real world. The BIM model, uploaded on a usBIM.platform®, is accessible online in each stage of the service life cycle of the building and provides access to every information (data, data sheets, properties) associated with each object in the model (BiblusBIM, 2020). The BIM platform is a real data sharing environment and gives the possibility to use advanced functions, allowing through a specific Cloud infrastructure, to handle online the digital model and to carry out simulations with Virtual Reality and Immersive Reality tools.

BIM and IoT for Ambient Assisted Living | The below-mentioned experimentation[8] was developed when we were still unaware of the transformations that the pandemic emergency would create in the health and assistance sector, hence in the Engineering and Construction Industry (AEC), and in the global society. However, some considerations were under development, and although they refer to a different time context, are very much in line with the needs of the unique moment we are living in. The need to accelerate the digital transition, computerise building processes, and make health and assistance services accessible remotely, are fully applicable to the solution of some current problems, such as social isolation, emphasised by the imposition of physical distance or home care and nursing treatments, with direct positive effects on the physical and mental health of particularly vulnerable people, such as the elderly (MASS, 2020).

The study has proposed an Ambient Assisted Living (AAL) digital model for the elderly, whose digital representation was used as a supervision tool and as a methodology to ease the interoperability of information concerning planned management of activities and user behaviour, considering the introduction of IoT devices in the environment and the information and communication infrastructure linked to it. The study has







Figg. 20-25 | Graphic-technical drawings of the digital model of the CURAPods project, Carlo Ratti Architetti Associati (source: dezeen.com).

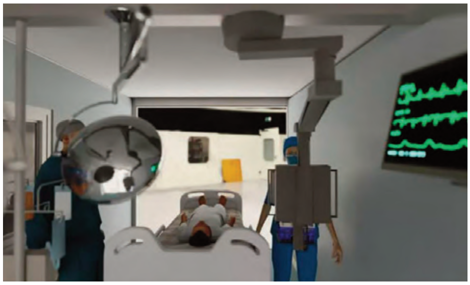


Fig. 26 | BIM at the service of emergency, rendering of the CURAPods project created with the BIM software Edificius® (source: bim.acca.it).

followed a parametric approach to modelling and Facility Management in health and assistance fields: through the creation of a data-set of parameters and attributes associated with IoT sensor technologies, a structured model of digital facilities was defined to control the AAL, starting from the creation of its digital model. Through the modelling of four house units for the elderly, optimised design solutions were investigated, starting from the correct spatial layout and the introduction of IoT technologies for energy management and environmental comfort, health monitoring and personal assistance, safety control and ensuring the safety of the elderly user (Fig. 27).

The structure of the model is based on an ‘information database’ within the BIM model including all the data referred to the housing module and the Artificial Intelligence systems (e.g. sensors and actuators) in it (Fig. 28). The monitoring infrastructure is based on a network made of various smart devices, whose informations, analysed and explained via a ‘middleware’, can be collected in a ‘server’ to enable the subsequent update of the digital model and the interaction with a ‘web platform’ of services related to the person, the building and the analysed organisation. Starting from spatial information, the ‘relational database’ (Fig. 29) in the BIM model was implemented with the data concerning the sensor technologies and automation systems in the digital environment (e.g. identification, quantity, position, parameter to be monitored, etc.) and used during the design development stage to identify the single components to trace information on the devices added in the house modelling (Fig. 30). Each element of the project is linked to an identification tag that enables to unambiguously recognise the single components, new parameters and characteristics are linked to them (e.g. ID, Date/Time, Location, Parameter, Status, Unit of measurement, Value, etc.; Fig. 31), whose information, tracked by devices, can populate the database operating within the digital model according to bidirectional informative fluxes.[9]

The information on the model has then been defined with a ‘semantic structure’ (Simeone and Cursi, 2016) based on the standard format IFC[10] (Industry Foundation Class) to be shared with each stakeholder[11], to enable the interchange of information not only between different softwares[12], but also with data management platforms. The classification of each device in the .IFC format, defined within the general category ‘data devices’, was useful to recognise the smart device category according to a stan-

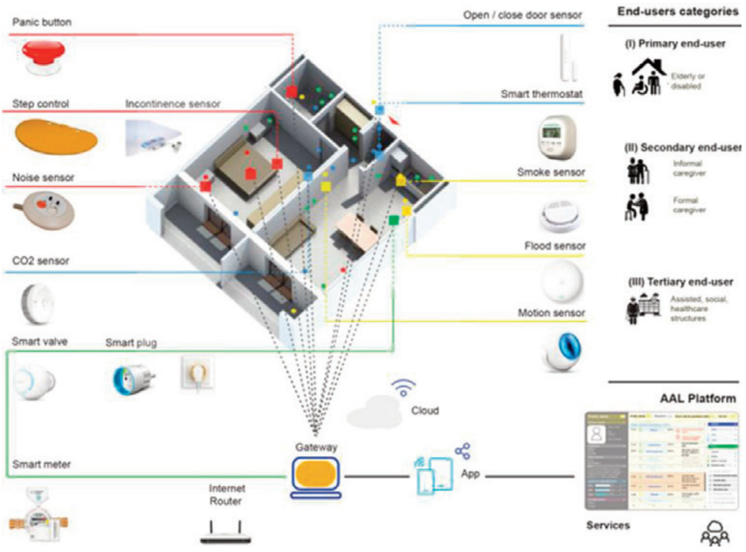


Fig. 27 | Model of the assisted house (AAL) for fragile users, IoT technologies and interaction with the ICT service platform (credit: A. Mangiatordi, 2020).

dardised coding (IfcSensor) linked to a specific element (IfcSensorType) recognized as ‘sensor’. Each device was then added to the BIM model as a new component of the category ‘data devices’, giving each element the relative propriety (IfcSensorType_PropertySet; Fig. 32). The data collected in the .IFC format can be accessed through external applications or functions that can interact with the BIM model, such as to make it interoperable. For example, they are useful to reprocess information needed for medical records or able to simulate emergency events occurring in real-time or to interact with different service platforms, and the software applications normally used for Facility Management operations.[13]

The access to the data occurs in a common BIM environment[14], as an information container – geometric and semantic – concerning the housing model. The data referred to the devices, traced and combined in the BIM model, can be analysed for different purposes, to enable energy, welfare or health services, as well as being displayed and made accessible to users for different purposes. The structure of the model can be shared and used by every worker of the process, both during the project stages and the operational and management stages, within the whole building life cycle. The use of a web platform can facilitate the visualisation of devices in the environment and the trend of parametric variables over time (Fig. 33). The implemented digital process is particularly effective because of the future possibility of accessing ICT/IoT services for the Facility Management referred to the person and built environment, manageable also remotely.

Results and Future Developments | The study, carried out during the research, has led to the development of a computer data simulator: the ‘asset’ of prepared BIM cate-

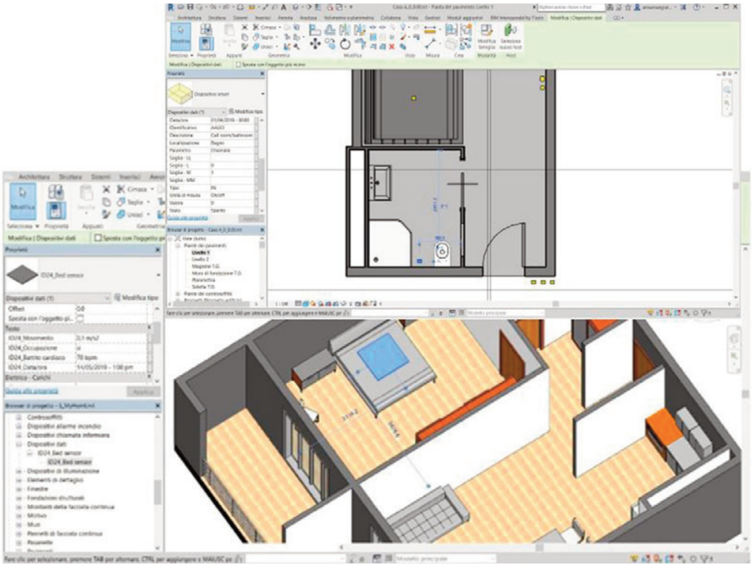


Fig. 28 | Digital model of an assisted house unit (AAL) for fragile users created with Autodesk Revit® software (credit: A. Mangiatordi, 2020).

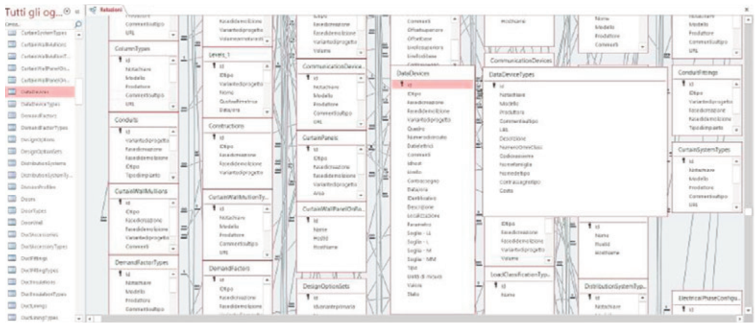


Fig. 29 | Relational database structure at the base of the digital smart model implemented (credit: A. Mangiatordi, 2020).

gories referred to a selected set of housing units, IoT devices and parameters concerning different reference scenarios. The project has used the parametric and interoperable nature of BIM tools, allowing the development of an evolved digital model, used in the design stage to reduce error and trace information concerning IoT devices placed in the environment. The harmonisation of data according to common and open formats (Dave et alii, 2018), makes them easily accessible, quickly available, sharable, updatable and implementable. This aspect provides for better adaptability of the model to specific project needs and requirements on particular environment conditions (e.g. temperature, CO_2, etc.), danger (e.g. the user falls, goes away from home, etc.), safety (open door, presence of gas and fumes), and health control (e.g. checking body temperature, weight, etc.) of the user.

The web platform will enable to view data concerning the devices, useful to activate preventive or corrective response actions to specific environmental condi-

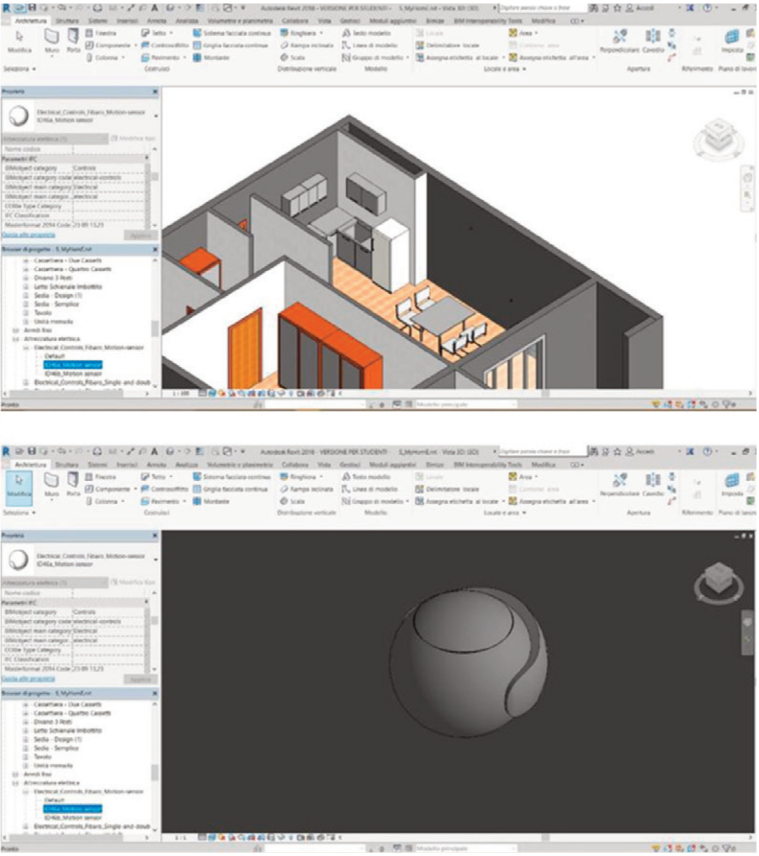


Fig. 30 | Modelling of a housing unit and placement of a smart device (example configuration) in the BIM platform of Autodesk Revit® (credit: A. Mangiatordi, 2020).

tions (e.g. control of indoor comfort conditions and air quality, the zoning of rooms according to certain functions, etc.) or specific needs of the users (e.g. displaying messages and alarms, responding to specific required services such as dressing, cleaning the room, vital signs monitoring, etc.). A future stage of the ongoing research will concern: the development of a systematised framework of environmental and technological requirements for elderly housing considering the renewed needs that emerged during the pandemic; the optimisation of housing models following flexibility and adaptability criteria in time, by adding filter and connection spaces, common spaces to stimulate new forms of collectivity and social interaction; the extension of the model to the entire building or district, including the integration of outdoor and neighbourhood spaces, by using interoperable BIM/GIS procedures; the optimisation of the interaction between web platform and BIM model, by testing further applications, devices and functions in addition to those created so far.

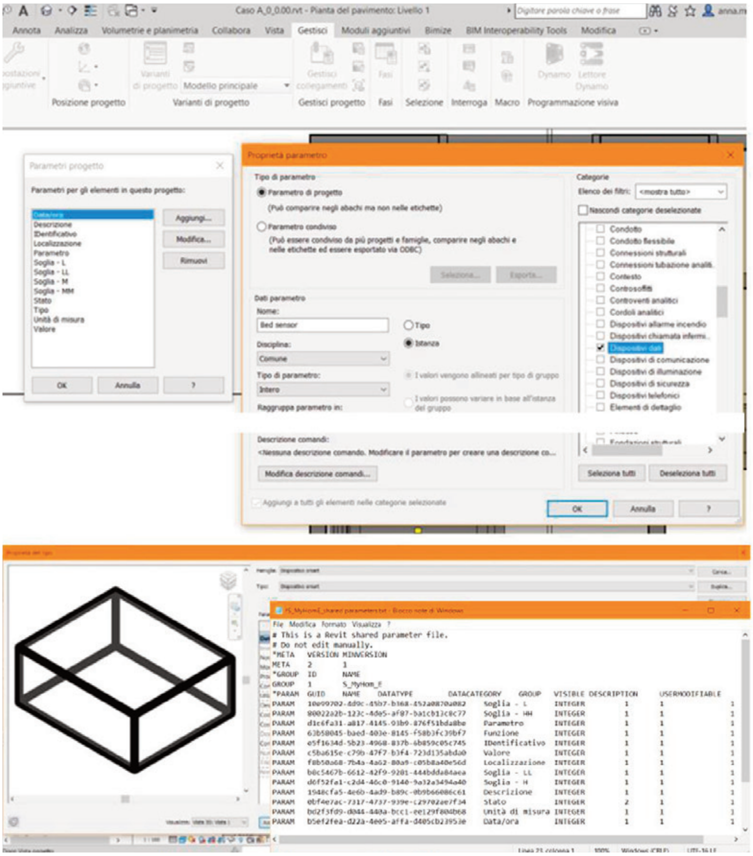


Fig. 31 | Shared project parameters applied to smart devices: an example of configuration (credit: A. Mangiatordi, 2020).

The design approach adopted has led to the definition of spatial configurations, in which the technological equipment can also be implemented at a later stage, imagined as an 'open system' continuously updatable and implementable. The modelled technical elements could allow the right placing and integration, even in the future, of other sensor devices aimed at monitoring vital parameters: emergency and care supplies and equipment. The results achieved with this research, although incomplete and referred to a few possible applications, are an example of the potential that the most advanced digital tools could offer in optimizing the design and management process of future building types and organisations in the health and assistance sector. The digital model created, although referred to the specific case of AAL for the elderly, is currently undergoing further optimisation, adaptable to future applications extendable to other building types in the healthcare and assistance fields and to different user categories, opening up the research to possible new experiments in this field, important for the building industry.

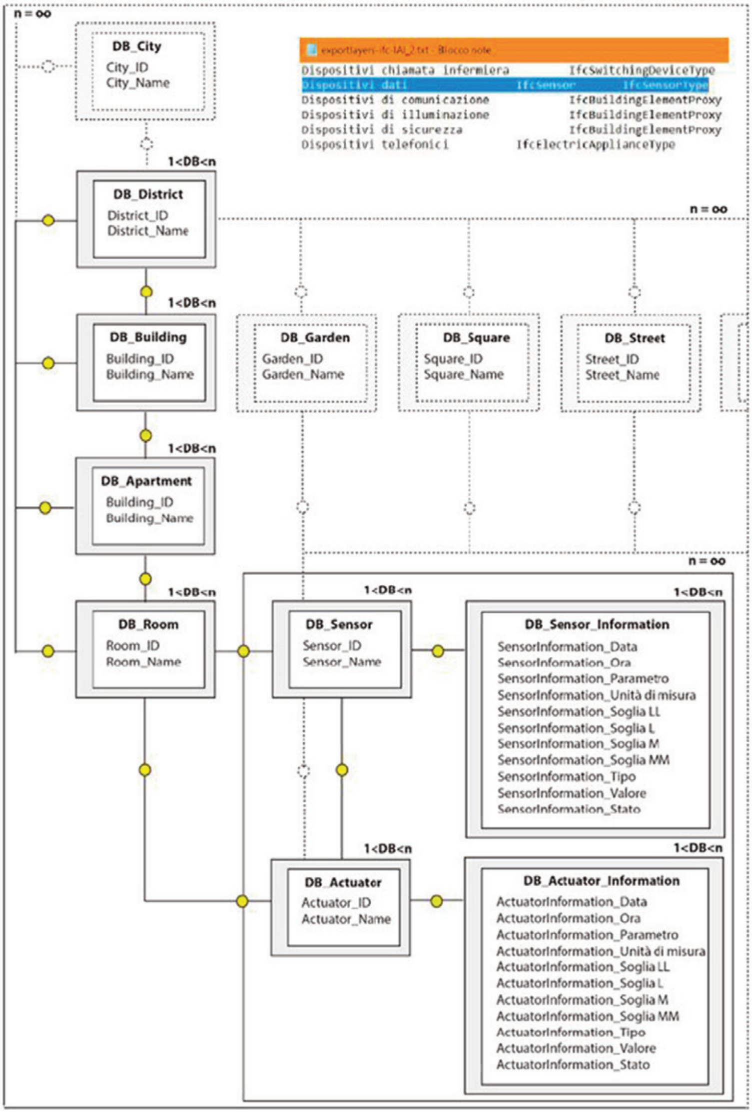


Fig. 32 | Organization and structure of the BIM model: a connection between spaces, smart devices and parameters to be controlled (credit: A. Mangiatordi, 2020).

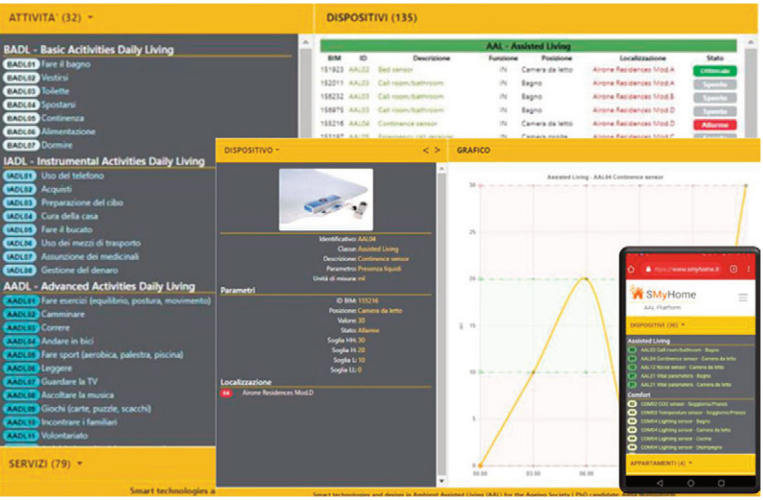


Fig. 33 | Graphical interface of AAL platform and devices display: an example of configuration (credit: A. Mangiatordi, 2020).

The perspectives outlined in this sense are useful to trace the path that the whole industry could follow on processes and product digitisation to reach new sustainability goals. They are useful also to improve the efficiency and productivity of workers in the sector and to ensure health and safety for users in the environment, within a new dimension of relations and contamination between real and virtual, material and immaterial, analogue and digital (Deng, Menassa and Kamat, 2021), benefiting from the value potential that would result from the interaction between BIM tools, Artificial Intelligence systems and ICT applications for handling health and care services and the performance of associated Facility Management activities (Ghaffarianhoseini et alii, 2017).

Conclusions | Since the early stages of the pandemic, architecture has represented a useful means to support first-line health care providers, facing unprecedented clinical demand. Building specific hospitals and assistance facilities, made up of modular or off-site units, has made the workers in the building industry true emergency responders, offering high-quality projects in exceptional circumstances. The experimental examples of newly developed practices, although referred to as a temporary situation, show that is possible to create in a short time architectures for environmental and technological high-performance health and that the digitisation and informatisation of the built environment are the best paths to overcome future crises. In this context, the role of the designer is still to improve, through architecture, the quality of life for people, using project tools and methods now evolved, but adapted to the current and future needs of the community. In this scenario, the collaborative approaches to the design can be the most immediate response to the requests for first aid and assistance to the needs of particularly vulnerable people, such as sick or chronically ill people, people with impairments and the elderly (De Giovanni, 2018). Another one is the use of methodologies typical of computer modelling to facilitate the creation of advanced building models in a short period and at an affordable cost.

However, digital innovation can contribute to further improving the effectiveness of the health or assistance service, creating new opportunities for physical and social interaction, enhancing user experience and improving work conditions of hospital or social care workers. As highlighted in the mentioned research case study, the massive diffusion of digital technologies and the use of BIM tools and computer data, accessible through web-based platforms, could contribute to improving some services, such as setting up the electronic health record, filling in medical records, 3D navigation in hospital or assistance environment, the use of environmental and energy consumption monitoring equipment, security control and patients or fragile users health control, particularly suited for the emerging needs imposed by the pandemic.

Therefore, pushing towards the digitisation of the healthcare sector and the reliance on telemedicine find fertile ground in this particular emergency, but adapt perfectly to the prior need to accelerate computerisation processes of the built environment and health and assistance services. In this diffused and pervading transformation, the contraposition between the real analogic world and the virtual digital world is increasingly weaker, reducing the limits and overcoming the boundaries of relationship spaces, defining new interaction relations between humans and machines, through hyper-connection and constant sharing of information in real-time (Campioli, 2020).

Notes

1) In line with the research purposes of Horizon Europe, Pillar II – Global Challenges & European Industrial Competitiveness (Cluster 'Health', 'Digital Industry and Space'), via specific programs such as EU4Health, and the sustainability aims of Agenda 2030 (SDG3 'Good Health and Wellbeing', SDG7 'Affordable and Clean Energy', SDG9 'Industry, Innovation and Infrastructure', SDG11 'Sustainable Cities and Communities') the use of robotic systems, the use of advanced devices, the introduction of smart components and automation systems in buildings, the creation of proximity networks and infrastructures for telemedicine and healthcare, and the digital transition through investments in research and development are envisaged. For more information, see the websites: ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en [Accessed 16 July 2022]; unric.org/it/agenda-2030/ [Accessed 16 July 2022].

2) On 30 January 2020, the World Health Organization declared a 'Public Health Emergency of International Concern' the Coronavirus epidemic diffused after China reported a cluster of cases of pneumonia of unknown aetiology on 31 December 2019. Due to the extent and ease of contagion and the containment measures taken so far, the state of a health emergency, still ongoing, was extended temporarily until 31 March 2022. For more information see the WHO, 2021 report.

3) Next Generation EU, a tool for recovery, aims to 'better rebuild', following the support of the green and digital twin transition in the health and assistance field, to ensure personalised and effective care and a comprehensive digitisation of health systems. For more information, see the website: ec.europa.eu/info/strategy/recovery-plan-europe_en#nextgenerationeu [Accessed 16 July 2022].

4) Within the PNRR 'Mission 5 – Social Inclusion', specific funds were allocated for renovation projects of assisted living residences or nursing homes for elderly and the creation of new housing forms, even temporary, to prevent institutionalisation, as well as financial obligations to support home-based care and assistance activities for people with impairments and the elderly. The PNRR 'Mission 6 – Health' aims in particular to strengthen proximity networks and intermediate facilities for telemedicine and assistance, directing innovation and research towards the digitisation of the Italian National Health Service (SSN). For more information, see the website: governo.it/sites/governo.it/files/PNRR.pdf [Accessed 16 July 2022].

5) The Italian Ministerial Decree No. 312 of 2 August 2021, amending the previous Italian Ministerial Decree No. 560 of 1 December 2017, provides specific measures for interventions on buildings and infrastructures useful to the implementation of the funds provided for in the PNRR. It envisages bonus scores for the use of BIM in design, according to criteria that may favour the development of innovative methodologies for project control and management, together with aspects of information model management, as well as the use of augmented and virtual reality tools, sensor-based monitoring systems, or electronic methods and tools aimed at reaching environmental sustainability goals (also following Green Public Procurement principles). For more information, see the website: mit.gov.it/normativa/decreto-ministeriale-numero-312-del-02082021 [Accessed 16 July 2022].

6) The CURA Pods project was created with the support of the World Economic Forum – Covid-19 Action Platform and Cities, Infrastructure and Urban Services Platform, an international team of expert professionals. For more information, see the websites: carloratti.com/project/cura/senseable.mit.

edu/cura-configurator/andcurapods.org/ [Accessed 16 July 2022].

7) A Digital Twin is a digital representation based on the data of something existing typically in the real world. The immediate benefits of the creation of a Digital Twin are embedded digital technologies. By sharing data and information in real-time they can allow to save great quantities of energy and resources, and to access to innovative digital services, creating new improvement, productivity and creativity opportunities for the users, and optimising the functionality of buildings through control and monitoring processes. More information on the Digital Twin concept can be found in the ARUP, 2019 report.

8) The paper presents the results of the PhD Thesis written by the Author (Mangiatordi, 2020), together with some university research carried out in the PDTA and DIAP Departments of 'Sapienza' Università in Rome, still ongoing: 1) 'Smart Technologies and Design in Ambient Assisted Living (AAL) for the Ageing Society' (2016-2017), Scientific Supervisor Professor E. Arbizzani ('Sapienza' University of Rome), Operational supervisors P. Clerici Maestosi (senior researcher, Enea) and P. Civiero (RTDB researcher, University 'Roma Tre'); 2) 'Smart Housing Design per l'utenza fragile – Nuove forme abitative e tecnologie a supporto della qualità della vita attiva degli anziani' (2019-ongoing), Scientific Supervisor Professor L. Reale ('Sapienza' University of Rome); 3) 'Senior Housing and Smart Technologies for the Elderly – Modelli tipologici e servizi digitali per il progetto e la gestione delle residenze per anziani' (2020-ongoing), Scientific Supervisor Professor E. Arbizzani ('Sapienza' University of Rome).

9) The data import process in the database was supported by the Revit DB-link® app which, through the link with external databases and servers, allows to continuously update the informational content of the project.

10) ISO 16739-1:2020 – Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries.

11) The informative model is organised according to the guidelines of the UNI 11337-1:2017 standard and is based on an open and interoperable format, following the international ISO/TS 12911:2012 and ISO 16739-1:2020 standards.

12) To process data for the assessments on the energy-environmental and visual-lighting comfort the interoperability with some softwares capable of communicating with the IFC standard was considered: Autodesk Ecotect®, Energy Plus®, Dialux®, as well as the Mantus Acca Software® for maintenance activities. This stage is under verification and implementation.

13) For example, reference is made to the COBie format capable of handling all the digital facilities (e.g. no. of people in the room, staff assigned to perform specific activities, presence of users, reading of device parameters, etc.)

14) ISO 19650-1 Common Data Environment, 'Agreed source of information for any given project or asset, for collecting, managing and disseminating each information container through a managed process'.

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