2023 European Conference on Computing in Construction
40th International CIB W78 Conference
Heraklion, Crete, Greece
July 10-12, 2023

DIGITIZATION AND DESIGN FOR SOCIAL INNOVATION. A CO-DESIGN MODEL FOR PRISON SPACES

Giulia Rubiu[1], Emanuela Quaquero[1], and Barbara Cadeddu[1]
[1] University of Cagliari, Department of Civil Engineering, Environment and Architecture, Italy

Abstract

This paper presents the results of a survey on the potential of applying Building Information Modelling, Virtual Reality and Augmented Reality tools to the context of designing Juvenile detention centres. Testing on a specific case study highlighted the main advantage offered by computer and network technologies, i.e., the maximization of the interaction between designers and stakeholders, bridging the gap between technical and common knowledge. The design and co-decision models tested, based on the use of inclusion methodologies supported by technological tools suitable for the particular study context, have made it possible to overcome the non–expert–user difficulties of understanding the technical documents and allowed to work in accordance with incremental logic, whereby the project is built, evaluated and corrected by successive approximations, taking into proper account problems and actions as a whole and in their interrelationships.

Introduction

The architecture of detention centres in Italy reflects the spatial practice of "containment", as demonstrated by the persistence of a distribution model based on a rigid functional organization of the cells, which are almost always inadequate to meet the purposes of re-educational and re-socialization enshrined in the Constitution of the Italian Republic (Scarcella et al., 2001). The adoption of an approach capable of reconciling the needs of detention with criteria related to the quality of living and working environments in a rehabilitative key could help to overcome this segregating paradigm and to humanize places of detention (existing building or new ones), facilitating the recovery and reintegration of the offenders into society. This contribution describes the results of an original experience that saw the light within the Department of Civil, Environmental and Architecture Engineering (DICAAR) of the University of Cagliari and hinged on a broader interdisciplinary project called "Fuoriluogo. Rethinking the spaces of the Penal Institutions for Minors (I.P.M) of Quartucciu with its inhabitants", aimed at responding to the solicitation launched by the public consultation on penal execution (Gli Stati generali dell'Esecuzione Penale, 2016) (Decree Low of 8 May 2015). Articulated in an intense program of education and research initiatives, "Fuoriluogo" proposed, among others, a theoretical-practical reflection on the re-organization of the internal and external spaces of the Institute located in Sardinia, using the co-design planning approach. The full involvement in the spaces regeneration process of all the people involved as users (the penitentiary staff, comprising the direction and the police officers with educators, teachers, psychologists, volunteers, and the inmates themselves), made it possible to carry out an important mutual knowledge process by bringing together needs, visions, perceptions, critical issues, and instances in a common project. This experimentation found support in some non-conventional co-design models based on the use of inclusion methodologies (Cadeddu, et al., 2019). Equally, implementing the Building Information Modelling (BIM) methodology proved to be particularly effective, giving the project a stronger connotation of hybridizing approaches and instances. Furthermore, the association of the latest developments in Virtual Reality (VR) and Augmented Reality (AR) with BIM allowed an additional step forward, guaranteeing non-expert users' rapid understanding and sharing of design choices and the overcoming of linguistic and technical skills barriers.

From participatory design to co-design for social innovation

Almost 50 years after the publication of Giancarlo De Carlo's essay "An Architecture of Participation" (De Carlo, 2013) (Royal Australian Institute of Architects-Melbourne Architectural Papers, 1972), the theme of the stakeholder's direct involvement in urban decision-making processes, is more relevant than ever. This paper cannot dwell on the forms and evolutionary lines that public participation has taken over time, it is a matter of fact that in Italy, the approach also known as bottom-up, which involves the future users at every stage of the plans/projects, has gone through different interpretations collecting contradictory results, often proving to be ineffective in terms of developing "collective intelligence" processes. The 21st century has seen the emergence of a new tension towards civic, political, and social mobilization aimed at "making the city" that has expressed itself in a multiplicity of experiences of resistance to top-down decision-making processes, or, again, through spontaneous practices of re-use of spaces by individuals or groups of citizens, in response to new emerging needs (Inti et al., 2014). In some cases, the dialectic between bottom-up processes, civil claims, and institutional responses led to shared solutions that have been recognized by the Italian legal system, producing significant changes in the contexts concerned. Just think

of the development of sharing practices such as co-living, co-working, community gardening, carsharing, food co-ops, joint workshops, collaborative urban economy initiatives, and regeneration of urban commons. These forms of planning shown in the space by social actors united by a common goal are called "social innovation" (Mulgan et al., 2010). The transformative nature of these practices certainly takes on a political value in its ability to reconfigure places, ways of use, and behaviour, but it does not lend itself (even in cases in which it is institutionalized) to solving problems that transversally concern different sectors (social, urban planning, economic, etc.) (Manzini, 2018) and must necessarily be faced in an integrated way by public policies. Indeed, Manzini points out that for these initiatives not to become self-referential or lose their initial values, it is necessary to create adequate conditions/infrastructures and address them correctly. This is where "design for social innovation" comes into play, an "expert design" that has cultural, practical, and technological tools, applicable to any type of problem to integrate and promote the design skills of "others" (non-expert people). As we will demonstrate later, the design, thus meant, seems to be the most suitable tool for the emersion of instances and the stimulation of forms of belonging and care for places when the opportunity for the "inhabitants" to participate in decision-making processes and choices in the definition of the conditions of their life contexts is severely limited (Inti, 2019).

Digitalization and new scenarios for co-design

Building Information Modelling

The Building Information Modelling (BIM) methodology represents a real paradigm shift in the construction field as it creates the conditions for multicriteria analysis; it allows different and often contrasting specialized skills to be brought together. BIM methodology is still recognized as a winning strategy in the implementation of new construction; but currently, it is also beginning to spread widely to support the management of existing building stock (Sanna et al, 2017), (Desogus et al, 2021). Defined as the keystone in the process of digitalization of construction, the BIM methodology allows the development of a digital model which faithfully simulates the behaviour of the real building, within which all the knowledge concerning the building itself during all phases of its life cycle is capitalized and organized. In this way, the best conditions for the integration of all actors involved in the process having different specialized skills and/or needs are created. These features show that this methodology can effectively support participatory planning, in which the "design" results from an integrated and multidisciplinary vision (Türkyılmaz, Kizilkan, 2019). This approach allows the maximization of the quality of the final product, but also strongly increases the efficiency of the processes: the integration of all the actors involved from the beginning in the specific process and the possibility of working with simulations guarantees the rapid and correct interpretation of the design choices and more accurate analysis and control of the results. The information, which can be integrated and updated, will be the basis of all decision-making processes that will affect the building during its entire life cycle, facilitating the conscious and effective choice of solutions to be undertaken during the operation and maintenance of buildings. An important advantage of BIM tools is the possibility, starting from the building model that faithfully represents its current configuration, to quickly obtain an immediate simulation of possible intervention scenarios. The digital model created, in addition to containing the complete information set to support the decision-making processes that will affect the building during its entire life cycle, is an effective basis for producing 3D views and photorealistic renderings. Only technical drawings and two-dimensional diagrams do not allow the idea of the intervention to be clearly and effectively conveyed. Simulation is one of the best tools to be able to communicate with clients and project stakeholders, overcoming barriers related to technical skills and language. It is a tool that allows immediate feedback regarding the satisfaction index of the hypothesized solutions, and effective support to the participatory design process.

Virtual Reality

Virtual reality (VR) has applications and benefits in many fields: from entertainment to architecture, medicine, education, and many other areas (Cline, 2005). The National Academy of Engineering identified VR as one of the fourteen big engineering challenges of the 21st century (National Academy of Engineering, 2008). It consists of a set of static simulations that, when combined, provide a 360-degree view of the designed environment. There are two types of VR techniques: non-immersive and immersive techniques. Non-immersive techniques allow users to interact with the virtual environment through conventional tools such as a keyboard, mouse, and monitor. Immersive techniques allow for more realistic experiences, in fact, in this case, the user is surrounded by curved screens, is inside a Cave Automatic Virtual Environment (CAVE, a cube surrounded by monitors), or wears a Head-Mounted Display (HMD, a wearable tool that allows users to turn their smartphone into a real screen). Both immersive and non-immersive VR techniques can be integrated with the Building Information Model. In recent years, VR is a bet on by recreational and entertainment players but also by the scientific world, which is pursuing the path of digital innovation in developing new products and services.

Augmented Reality

Augmented reality (AR) is an interactive graphics system that allows one to act on a video image stream, modifying reality by adding, in real-time, virtual content and animations (Kipper et al., 2012). While at first this technique may be confused or overlapped with VR, AR differs significantly from VR. The difference between VR

and AR is that, in the first case, one is observing on a screen the projection of a fictitious world made entirely of virtual objects. In the second case, what is being imaged is an integration of real images and virtual objects. Interactivity is another key concept. The virtual objects that augment the video stream are not static but can perform movements and animations in response to human actions.

A co-design methodology for the "spaces of punishment"

We could say that the design of prison facilities in Italy is a topic "removed" from the traditional architectural and urban culture and public debate. There are no specific texts or manuals on jail construction, and we have a lack of studies and research in this area. The detention centres, always an exclusive prerogative of ministerial technicians, express in their spatial concept and functional organization of the spaces, homologated and replicable buildings, which exclude and are excluded from the urban context, responding almost exclusively to social defence needs (Zevi et al., 2011). It should be considered that the few experiments and research in the architectural field, aimed at finding a democratic model of detention buildings able to give adequate shape to the purpose of re-education and re-socialization of the sentence, can be traced back to those of Ridolfi (institutes of Nuoro and Cosenza, 1953), Sergio Lenci (District Complex of Rebibbia, 1959) and a few others. The need to bring attention to the architectural aspect of detention facilities and the requirement for innovation to the reference design criteria and the planning and management practices of penal institutions, arose again in 2015 when the Ministry of Justice appointed a Committee of experts, chaired by Glauco Giostra, to carry out a public consultation on penal execution called "Estates - General" (Decree Low of 8 May 2015) (Gli Stati Generali dell'Esecuzione Penale, 2016). The final document produced by the eighteen working tables of the National Assembly which involved more than two hundred experts from different cultural areas and professionals (operators, magistrates, architects, lawyers, teachers, experts, representatives of culture and civil associations), contains ideas and proposals to build the new rules to reform the enforcement of prison system. In the thematic table "Penalty space: architecture and prison", coordinated by the architect Luca Zevi, emerged several proposals, aimed at overcoming the "separate" character of the institution. Among all, promote a dialogue between the penitentiary Administration, Universities, Foundations, Research Institutes, Professional Associations, Local Authorities, Associations, and experts, for new buildings design/renovation projects criteria that may lead to the achievement of an architectural dignity of the penal execution spaces. The reform process of the Italian Penitentiary institutions (governed by Law No. 354 of 26 July 1975), slowed by the change of government, saw the enactment of three legislative decrees (No. 121,123,124 of 2 October 2018), which gave Regulatory implementation only to a part of the points originally contained in the enabling Law 23 June 2017, No. 103, betraying the innovative role of the Giostra Commission and without producing the desired change. Of particular interest here is Legislative Decree No. 121, which deals with the need to establish a Juvenile Justice System, which also regulates in detail some aspects of detention spaces.

The project "Fuoriluogo. Rethinking the spaces of the I.P.M. of Quartucciu together with its inhabitants".

The pilot project called "Fuoriluogo" responds to the requests launched within the already mentioned public consultation and proposes the "space of punishment" as a subject of specific disciplinary elaboration by the world of research and architectural design, involving a multiplicity of external competencies, especially in the legal, social, and cultural fields. It is formally recognized in the "Convention for the realization of educational and research activities", signed by the Department of Civil Engineering, Environmental and Architecture of the University of Cagliari and the Center for Juvenile Justice for Sardinia on 13 December 2016 and renewed in 2017 for three years, a document that includes in its scientific committee, among others, the architect Luca Zevi. The proposed methodology is aimed at involving and empowering prisoners and operators in the process of functional reorganization, management and care of their living and working spaces. It provides that teachers, managers, operators, students, and detainees would collaborate in the different steps of the redefinition and renewal process of the spaces of punishment (ideation, definition, and, in some cases, realization in self-building), according to an approach of penal execution focusing on the "active participation" of stakeholders, intended to provide a positive impact on the dynamics of the inmates re-socialization and re-integration into social life – society (Cadeddu et al., 2020). As already anticipated, the proposed approach is co-design, which involves stakeholders collaborating with designers at all stages of the process: from defining the functional program and new environments to testing possible scenarios. The first need emerged, is to develop a methodology which involves languages that could translate the requirements of each into clear and accessible design responses for "non-experts." Employing BIM methodology and tools to support the active involvement of stakeholders and facilitate the emergence of critical issues, opportunities, and needs is strategic. Since applying the BIM methodology to the existing building stock has as its first need to produce a virtual model ("digital twin") that faithfully represents the building in its real configuration and structures the information set necessary to outline appropriate intervention scenarios, the construction of the parametric model is an important part of the proposed methodology. Starting from the in-depth analysis of the available information set on the specific building, a selection was

made of what would be the subject of parametric modelling. The BIM model cannot represent the universal repository of all kinds of information but must be conceived within a highly finalized database. The proper execution of a project according to BIM methodology follows iterative working tasks, which direct designers to progressive stages of model development. The phase of georeferencing and topographic modelling of the site represents the preliminary stages in model development. The immediate next step is to create the "As is" model, the current configuration of the building to form the basis of the design phase, to record and manage knowledge regarding the functional distribution of interior and exterior spaces, materials, construction techniques used, conditions of deterioration, etc. Then, the creation of a parametric model of the building containing all the information related to the defined intervention scenario in terms of new spatial distributions, materials, colours, furnishings, etc., provides a three-dimensional realistic idea of the final outputs of the defined intervention scenario. In this sense, the use of the BIM model allows clear and quick communication to all the stakeholders regarding the details of the design choices and to have immediate feedback on their approval rating and the correspondence of the result to the starting instances. However, even this tool requires a certain degree of mental abstraction to imagine a real result in proportions and dimensions. For this reason, virtual reality (VR) can be successfully implemented. It is capable of fully representing surfaces, spaces, and light points and presenting the proposal in an even more comprehensible way to support greater involvement in furniture choices, including functional, distributional, and architectural evaluations (Delgado et al., 2020). The simulations can be extracted through Autodesk Revit software from the central model developed in the first design phase taking advantage of the cloud platform not only for its computational power but especially for its speed in joining static simulations to have a 360-degree view of the defined environment. The joint use of a smartphone with IrisVR's Scope app allows one to visualize VR panoramas on the smartphone itself by using it within Google

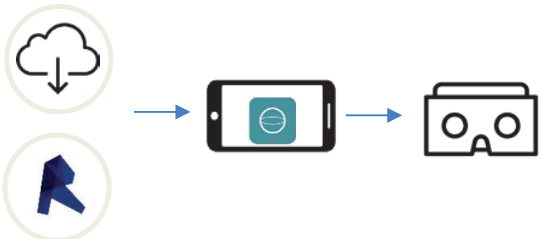

Figure 1 From cloud render to VR 360° simulations.

Cardboards. Another technology implemented in the co-design methodology proposed is Augmented Reality (Kouzeleas, 2022), which compared to Virtual Reality exploits a different approach, "enhancing" the real world with integrative information sets. By importing the central model into the open-source program Aumentaty, it is possible to experiment with the use of augmented reality. The Aumentaty application allows different users to enter and share several models, in the different formats allowed, including .obj. To visualize the model, reference elements (markers or fiducial symbols) must be created. These are elements that are recognized very easily by the camera software, which can have different shapes and characteristics (often the QR-CODE is used (Chua et al., (2018).

Figure 2 BIM information model and AR interaction.

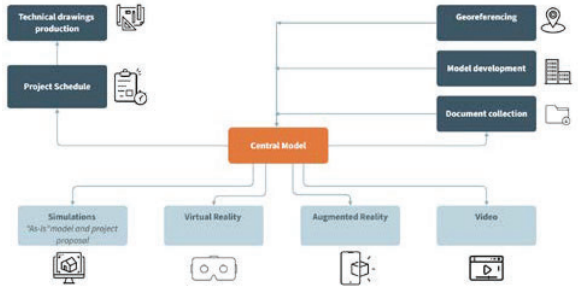

Figure 3 The workflow developed.

The case study: the penal institution for minors in Quartucciu

The Penal Institutions for Minors (I.P.M) of Quartucciu is the only institution in Sardinia aimed at ensuring the enforcement of sentences and custody of minors and over 80s; located in the rural area of Quartucciu, in the outskirts of Cagliari, the prison is not connected to the local public transport system. Built in the early 1980s, the I.P.M. exhibit the typical architecture found in maximum security facilities, bordered by a high wall and a double fence. Originally intended for the detention of high-risk adult prisoners, since 1983 it has been used as a correctional institution for minors. The structure is provided for a maximum capacity of 18 young men who committed crimes during the imputable age. If up to the year 2000, the detainees were almost all Sardinians, in the last twenty years the number of non-EU detainees has increased largely. The architectural complex is comprised of 4 buildings in a 9,000 square meters area. To access it is necessary to pass a system of fences and a 10 meters high wall. After the control point, you access an open court in which is located a four-storey block for the administrative offices, those of the educators, the kitchen, the canteen, and the barracks. From this building's ground floor, it is possible to access the two-story block (named

E block) chosen to carry out the renewal intervention. The two long corridors that lead to the two detention areas (block A and B) start from here. On the Block E ground floor, there are rooms for individual interviews with judges, lawyers, and family meetings, a multipurpose hall, a laundry, a carpentry, a bicycle workshop, and an internal open courtyard. On the upper floor, there are spaces for education, social and cultural activities, a library, a multipurpose room, and a space dedicated to multifaith prayer. Externally the institute is equipped with a soccer field in synthetic grass with benches, well maintained, a basketball field in a clear state of decay, and a clay space unused at the time of the research. From a technical point of view, despite the structure of the IPM presenting a good state of preservation, the envelope requires important maintenance. Even more relevant for this paper are the critical issues related to the living spaces, that emerged following the meetings with various stakeholders. From a strictly formal point of view, the mere application of the security rules that guided the design of the architectural complex results in the assemblage of cells intended as anonymous containers, organized along long and undifferentiated corridors strongly compartmentalized by armoured gates. The excessive repetitiveness in the organization of environments poorly adapted to the assigned functions contributes to the creation of spaces without identity. The furnishings, which tend to be fixed, are mostly waste objects and do not create comfortable. Moreover, the chromatic monotony, given by the obsessive use of shades of green (which should express stability, strength, and balance) produces indifference and alienation (Cadeddu, 2019). As explained above, applying the BIM methodology to an existing building need to produce a virtual model that represents the building in its current configuration and structures the information set necessary to outline appropriate intervention scenarios. For this reason, the construction of the parametric model of the IPM building was an important step of the work. Autodesk's Revit software is used for this purpose.

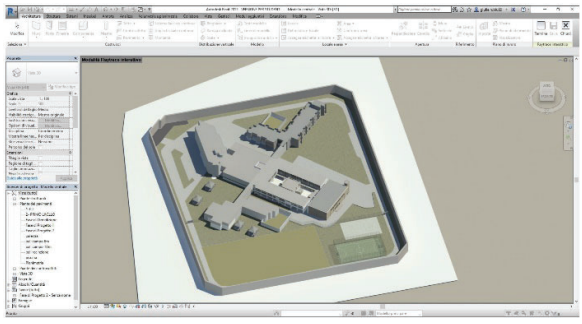

Figure 4 The current configuration of the IPM building.

Many inspections carried out pursued the purpose of integrating the acquired documentation, mostly paper or validating its congruity and consistency with the current state of the IPM building.

The design proposal

At the beginning of the process of developing a design proposal for the IPM, a series of targeted meetings were carried out with the techniques of "focus groups" and interviews, to detect the experiences and collect the needs, ideas, and proposals of the different organizational areas in which the detention building are articulated: management, administration, education, security, and detention. The design proposal developed focuses on the laboratories located on the second floor of Pavilion E. It proposes a new space configuration to encourage resocialization and improve the quality of the re-educational pathway of inmates, while always guaranteeing a high level of supervision activity. The laboratories thus conceived, will support a didactic strongly focused on professionalizing activities, aided by digital tools. The new environments should be able to host the various activities and educational projects planned by the prison administration, allowing training in different areas. Starting from the fact that juvenile detention is a residual measure and that the guests, and therefore also the projects, change frequently, the design proposal does not give a particular connotation to the spaces, except the doors: they were replaced with rotating panels, which allow to change the configuration of the space and regulate the permeability between inside and outside, breaking the closed symmetrical rigidity characteristic of prison construction. Through the demolition of some of the walls near the access to block E, in a central position, the new reading room and media library are obtained as places for socialization. Security in this open space, considered a priority by the operators, led to the definition of glass parts, ensuring not only excellent visibility and surveillance but also good natural daylighting. The bookcases were designed with a load-bearing structure of pipes and wooden shelves; the simple and cheap character is intended to ensure their self-construction by the inmates themselves, during a training workshop. The space of the corridors has been rethought to break symmetry and be able to give an identity to these rooms. In addition, the use of geometric chromatic devices on the horizontal and vertical surfaces (walls, floors, doors, and ceilings), generates an optical effect of space dilation. To improve the quality of spaces and views is included vegetation above the roof slabs. The design proposal also concerns the redevelopment of the Institute's outdoor area dedicated to sports activities. At the time of the project, this area was occupied by a well-maintained soccer field equipped with benches, a "basketball" court in an obvious state of disrepair, and a large space not currently used for any structured activity. The proposal started from the assumption that sport is generally configured as an educational opportunity capable of producing positive changes in the person, increased self-awareness, and attitude to coexistence. For this reason, strengthening the area dedicated to the physical activity of the inmate population is considered the key element in a systematic process of recovery and preparation for a return to society.

Among the critical issues to be considered in the reconfiguration of outdoor spaces is undoubtedly the need to supervise inmates in a very large area; for this reason, officer stations that allow a 360-degree view of the outdoor area have been included. In general, adopting the concept of dynamic surveillance, the outdoor area was divided into two distinct zones. In the first, occupied at the time of the project by an unused space, an 11-a-side soccer field is planned, subdivided in turn into four 5-a-side soccer fields, suitably delimited to allow people from outside the detention circuit to be able to use them as well. The fields could be used by associations to bring society closer to the prison and/or to encourage forms of self-financing. In the second area, intended primarily for the outdoor activities of the inmates, the proposal involves replacing the Basketball court, which is in an obvious state of disrepair, with a Beach Volleyball court. It also envisages the insertion of wooden structures capable of creating shady spots for recreation and the inmates' sociability; these structures are proposed as collected outdoor spaces, with the functionality of making the inmates feel in a protected but not oppressive context. Completing the seating proposal is an athletic track and free-body exercise equipment complete the design proposal for the outdoor space. The latter was designed by employing simple pipes to allow them to be made directly by inmates through workshop activities to be carried out within the prison facility. Also strategically placed are two pergolas, specially designed for officers to perform their control function, applying the concept of dynamic surveillance. The traditional means of architectural representation, usually technical two-dimensional drawings, are not sufficient to give a clear idea of the final outputs of a project to people who are not familiar with them. Technical 2D drawings are difficult to understand for the non-specialized user. In this sense, the use of the BIM model in this experimentation during all the phases of the design development allowed clear and quick communication to all the stakeholders regarding the details of the design choices and to have immediate feedback on their approval rating and the correspondence of the result to the starting instances. Working on the existing building stock involves the need to have a parametric model capable of representing the configuration that the design intervention will outline, keeping accurate track of the elements to be demolished and those to be rebuilt in a new logic. The “phases” tool available in Revit software was used for this purpose. Quantitative and qualitative data were integrated with the visions, perceptions, critical issues, and needs ("project assets") that emerged as a result of discussions with the warden, educators, teachers, psychologists, volunteers, prison police, and the inmates themselves. The creation of a parametric model of the building containing all the information related to the defined intervention scenario in terms of new spatial distributions, materials, colours, furnishings, etc., made it easy to start photorealistic rendering, a process of obtaining a realistic virtual image from a computer-processed three-dimensional model.

Unfortunately, the BIM model and renderings require a certain degree of mental abstraction to imagine a real result in proportions and dimensions. Although BIM models and rendering are useful for understanding the general appearance of a project, they do not communicate the spatial properties of the design, such as aspects of size, scale, configuration, of spatial connectivity. Often, these are the aspects that professional teams want to analyze when they carry out participatory design processes (Loyola et al. 2019). This issue was managed with the integration of virtual reality (VR). Thus, it made possible a full representation of the design choices in an even more comprehensible way to support greater involvement of all the stakeholders in the evaluation and validation process of the intervention scenario. The simulations were extracted through Autodesk Revit software from the central model developed in the first design phase. The joint use of a smartphone with IrisVR's Scope app allows one to visualize VR panoramas on the smartphone itself by using it within Google Cardboards. In this way, a true "immersion" in the results of the design choices was obtained.

Figure 5 The design proposal: a view of the corridor in front of the classrooms.

Figure 6 The design proposal: an internal view of the reading room.

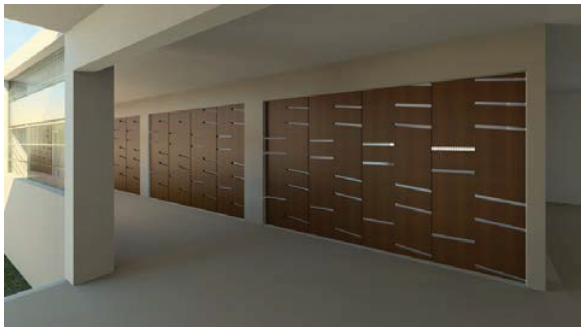

Figure 7 The design proposal: a view of the corridor in front of the laboratories.

Figure 8 The design proposal: an external view.

The AR technology implemented in this specific experimentation allowed for overcoming language barriers, concerning foreign inmates. Importing the central model into the open-source application Aumentaty allowed different users to enter and share the IPM model in the .obj format. In this specific case, to visualize the model, a floor plan of the building was selected as the marker. When the application installed in the smartphone detects this marker, it understands the location of the model, which is subsequently displayed. The software allows the content of different formats to be associated with the model: text, video, photographs, etc. In our case, the application allowed texts and dimensions to be displayed according to different languages and measurement systems to support communication with a multi-ethnic user base.

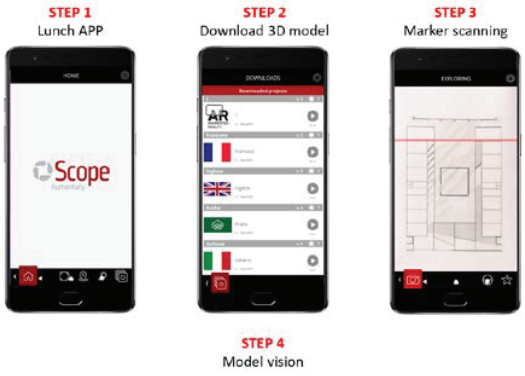

Figure 9 Use of Augmented Reality for language and unit selection.

Conclusions

The use of BIM methodology and tools in association with virtual and augmented reality allowed for the testing of a participatory model with a strong inclusive vocation. The elaboration of virtual simulations related to the possible scenarios of the re-functionalization of the spaces and the possibility of total immersion in the environments, guarantees the rapid understanding and sharing of the choices made, the overcoming of language and technical barriers (Ashour et al., 2022), and the improvement of dialogue with the weaker social partners. The experimentation conducted as part of the project "Fuoriluogo. Rethinking the spaces of the Juvenile Penitentiary Institute of Quartucciu together with its inhabitants," focused on the development and testing of alternative models of co-design through innovative tools (BIM-VR-AR), allowed to enhance that concept of "project" in a complex and multidisciplinary vision by favouring the substantial contribution from "non-expert" users. Although the improvement of the design process is one of the undoubted benefits that emerged, the experimentation generated other positive spillovers. The involvement of inmates in the design process of the space, of which they are the main beneficiaries/users maximizes the sense of belonging and alleviates distress. Such involvement, appropriately guided by educators, prison police, and volunteers, is in line with the process of re-education and empowerment of the person subjected to a restrictive regime.

References

Ashour, Z., Shaghaghian, Z., Yan, W. (2022). BIM-Empowered Augmented Reality for Learning Architectural Representations." ArXiv 2204.03207.

Cadeddu B., Memoli. M. Salimbeni (2020). L'(in)habitable, Marseille. Des cachots aux étoiles. Une expérience d'architecture participative dans une prison pour mineurs. In AAVV L'(in)habitable, Marseille ISBN/EAN 9782919230303 Lingua (FR)

Cadeddu B., Abitare un'Istituzione Totale. Il progetto del carcere come infrastruttura sociale, pp.368-375 (2019), in AAVV Ricerca e Democrazia: il pensiero e l'azione, FrancoAngeli s.r.l., Milano, Italy. ISBN 9788891783806

Chua, M., Matthewsa, J., Love, P.E.D. (2018). Integrating mobile Building Information Modelling and Augmented Reality systems: An experimental study. Automation in Construction.

De Carlo G., (2013). L'architettura della partecipazione. Quodlibet - Abitare, Macerata. ISBN 9788874628018

Delgado J.M.D., Oyedele L., Demian P., Beach T., (2020). A research agenda for augmented and virtual reality in architecture, engineering and construction. Advanced Engineering Informatics.

Desogus, G.; Quaquero, E.; Rubiu, G.; Gatto, G.; Perra, C. (2021). BIM and IoT Sensors Integration: A Framework for Consumption and Indoor Conditions Data Monitoring of Existing Buildings. DOI:10.3390/su13084496. In SUSTAINABILITY - ISSN:2071-1050 vol. 13 (8).

Gli Stati Generali dell'Esecuzione Penale, 2016: Il documento finale https://www.giustizia.it/giustizia/it/mg_2_19.page. Tavolo 1 – Spazio della pena: architettura e carcere, coordinatore Luca Zevi (Abstract, Versione integrale della relazione, Raccolta degli allegati) https://www.giustizia.it/giustizia/it/mg_2_19_1_1.page?previsiousPage=mg_2_19_1.

Inti I., Cantaluppi G., Persichino M.(2014). Temporiuso. Manuale per il riuso temporaneo di spazi in abbandono. Altreconomia Ed. EAN: 9788865161265 · ISBN: 8865161264

Inti I. (2019). Pianificazione aperta. Disegnare e attivare processi di rigenerazione territoriale, in Italia. Milano LetteraVentidue. Ibn 9788862422857. collana Alleli | Research.

Kipper, G., Rampolla, J. (2012). Augmented Reality an emerging technologies guide to AR. USA. Elsevier.

Kouzeleas, S. (2022). Scientific impact of architectural indoor augmented reality 3d digital representations. International Journal of Advanced Research (IJAR).

Loyola M., Rossi B., Montiel C., Daiber M. (2019). Use of Virtual Reality in Participatory Design. Conference: Architecture in the Age of the 4th Industrial Revolution. 37 Education and Research in Computer-Aided Architectural Design in Europe (eCAADe).

Mulgan G., J. Caulier Grice, Murray R. (2010). Social Innovator Series. The young foundation.

Manzini E., Politiche del quotidiano. Progetti di vita che cambiano il mondo. (2018). Roma, edizioni di Comunità
ISBN: 8898220812 - **EAN13**: 9788898220816

M.S. Cline, Power, Madness & Immortality, The Future of Virtual Reality. (2005). University Village Press.

National Academy of Engineering, Grand challenges for engineering, National Academy of Engineering, 2008, http://engineeringchallenges.org/challenges.aspx.

Sanna A., Monni G., Quaquero E.: (2017) The "Mandolesi Pavilion": an information model for a process of integrating multidisciplinary knowledge. TEMA: Technologies, Engineering, Materials and Architecture. Volume 3 n.1(2017). ISSN 2421-4574.

Scarcella L., Di Croce D. (2001). Gli spazi della pena nei modelli architettonici del carcere in Italia. Evoluzione storica. Caratteristiche attuali – Prospettive, in Rassegna Penitenziaria e Criminologica 1/3 2001.

Türkyılmaz E., Kizilkan M.B. (2019). A Conceptual Idea of Participatory Design with BIM. 9th AicE-Bs International Conference. Lisbon.

Zevi L., Anastasia S., Corleone F. (2011). Il corpo e lo spazio della pena. Architettura, urbanistica e politiche penitenziarie, Ediesse, Roma. EAN: 9788823016019 ISBN: 8823016019