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AI, Metaverse and co-design for social innovation: an application protocol.

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Abstract. Social innovation is a collaborative process that addresses complex problems through recombining resources, constructing networks, and adopting design tools. In this context, generative and conversational AI supports data analysis, knowledge synthesis and the production of operational toolkits. At the same time, the metaverse enables immersive, inclusive co-design spaces that overcome geographical and temporal barriers. The article analyses the potential of integrating artificial intelligence, the metaverse and co-design practices in social innovation. It discusses empirical experiences conducted in Milano and Palermo, developed in the OSMOSI action research project. It highlights opportunities and critical issues in the use of emerging technologies in urban regeneration and cultural innovation processes. It proposes an application protocol. This replicable protocol integrates digital tools and participatory methodologies, with implications for researchers, policy makers, and local actors.

Keywords: Artificial intelligence, Metaverse, Co-design, Social Innovation.

1 Introduction

Social innovation represents an emerging paradigm in contemporary design, characterised by the search for creative, sustainable solutions to complex social problems.

According to Manzini [1], social innovation is defined as “a new idea that works in achieving social objectives”. More comprehensively, it is described as “a process of change that emerges from the creative recombination of existing resources (from social capital to historical heritage, from traditional craftsmanship to accessible advanced technology), whose goal is to achieve socially recognised objectives in a new way”.

Social innovation, therefore, is one of the solutions to systemic problems that arise at both global and local levels. The use of design methodologies, tools and skills enables social innovation to become more resilient and sustainable [2].

At the same time, the advent of generative artificial intelligence (AI) and metaverse technologies has opened new frontiers for social innovation, offering advanced digital tools that can enhance collaborative processes and democratise access to design.

Integrating these emerging technologies with co-design for social innovation raises fundamental questions about intervention models, application protocols and evaluation methodologies. While the potential of such integrations appears significant, the scientific literature highlights the need for structured recommendations to guide designers, researchers, and policymakers in effectively implementing AI-metaverse solutions geared towards social change.

This article analyses areas of application for the use of AI and the metaverse as design tools. The aim is to identify recurring patterns, emerging best practices, and critical challenges, and to define them through the experiences of an applied research project (OSMOSI), as well as a protocol for their application in co-design for social innovation.

2 Scientific background

Design for social innovation [3] [4] [5] appears in the contemporary context as a practice-based design response and as a field of research interested in addressing open, dynamic, interconnected and complex problems [6] [7] [8] concerning social, economic and natural systems.

Design for social innovation aims to solve community problems by recombining available resources, creating new social relationships and strengthening stakeholder networks [2]. It is therefore an approach that aims to solve social problems by co-creating innovative solutions [9].

The co-creation of solutions can take place through what we call co-design. Its roots lie in Scandinavian participatory design, where workers were actively involved in developing technologies in the workplace [10]. Co-design has established itself as a collaborative approach to innovation in socio-technical contexts since the late 1970s.

Over time, this approach has evolved and been adapted across different sectors, extending to urban planning, public services, healthcare, education, and social innovation [11] [12]. Co-design therefore "refers to the creativity of designers and people not trained in design working together in the design development process" [13] and is a practical application of participatory design: it retains its participatory, contextual and democratic roots, but institutionalises these principles through user-centred design practices, social science methods, facilitation tools and a particular focus on experiences and service innovation [12].

It has evolved as part of a broader participatory shift in design that has radically changed both the objects designed and the design processes themselves [14]. This evolution represents a shift from traditional approaches to more collaborative design methods. Co-design, therefore, offers an open and relational approach to generating innovative solutions to complex social challenges [11]. Its iterative process (understanding, ideation, prototyping and testing) supports co-creation from ideation to implementation [15]. It plays a key role in building trust, acquiring knowledge and responding to user needs over time [16]. This methodology is based on the principles of democratising the design process and valuing stakeholders' experiential understanding, which are particularly relevant when addressing complex social challenges that require contextually appropriate and culturally sensitive solutions.

Hence, in design for social innovation, co-design is an established methodology for actively involving citizens, users and stakeholders in decision-making and creative processes [4] [15] [16].

The complexity of human and artificial systems plays a crucial role in design for social innovation [9]. The relationship between digital tools and social innovation is characterised by complex integration, in which artificial systems work alongside human systems to address social problems through co-creative approaches. Digital tools, therefore, must be integrated with human systems characterised by different behaviours, needs and values. This integration requires understanding socio-technical dynamics, including social networks, collective decision-making processes and technological mediation. Digital tools play a crucial role in designing for social innovation. This implies that designers must consider the dynamic interactions between individuals, communities and advanced technologies. They must understand how these heterogeneous elements can interact, influence one another, and often generate unexpected results. In this context, the disruptive evolution of digital technologies has opened up new frontiers for co-design and social innovation, introducing tools that facilitate remote communication and act as true catalysts for creative processes.

Among these tools, AI and the metaverse represent a paradigm shift, opening new frontiers for the design of socially relevant interventions. Generative AI, with its ability to produce text (Large Language Models, LLMs) or images (text-to-image models), can enhance ideation and prototyping and provide advanced tools for analysis, automation, and the personalisation of experiences. At the same time, the immersive environments of the Metaverse and Virtual Reality (VR) offer new "spaces" for interaction, collaboration, exploration of future scenarios and social experimentation [17]. These technologies are not accessories, but new contexts for interaction and creation that redefine the limits of collaborative design. Despite the apparent potential of these technologies, their application in co-design contexts for social innovation is still in an exploratory phase [18] [19].

2.1 Approaches and applications of the metaverse and Generative Artificial Intelligence in co-design for social innovation

Integrating GenAI and the metaverse into co-design processes for social innovation presents a variety of application approaches that reflect the versatility and transformative potential of these emerging technologies. Their convergence in co-design offers unique opportunities for social innovation, enabling diverse stakeholders to engage in more inclusive and creative collaborative processes.

On the one hand, large language models and image generation algorithms offer new possibilities for supporting collaborative creativity and accelerating participation and prototyping cycles. On the other hand, the metaverse, defined as an ecosystem of interconnected virtual spaces where users interact through digital avatars, provides immersive environments that overcome the physical and geographical limitations of traditional collaboration, offering effective platforms for co-designing in complex social contexts [20]. It transforms how people interact with technology and simultaneously with the physical and digital worlds [21].

In the field of co-design (and design more generally), the adoption of the metaverse and AI involves different applications and action plans that, on the one hand, can enable the two technologies to communicate with each other, refine their responses and allow users to make proper use of them. Various areas of tools, applications, and emerging approaches in the social-community-urban sphere offer a dynamic picture of the context and approaches used:

Generative artificial intelligence and large language models. Generative AI is emerging as a catalyst for innovative collaborative processes. The application of conversational AI in value-sensitive processes represents a significant methodological evolution integrating ethical considerations into technological design. The use of chatbots powered by language models can facilitate structured dialogues on stakeholder values, demonstrating how AI can act as a neutral mediator in gathering and synthesising different perspectives, supporting the creation of frameworks that authentically incorporate community values into the design of intelligent systems [22]. However, even though conversational AI can support the structured extraction and synthesis of stakeholder perspectives, its neutrality cannot be taken for granted. The model's behaviour reflects the training data and prompt settings and therefore requires explicit governance, documentation, and human oversight to mitigate bias, omissions, and overly optimistic summaries.

In the educational context, integrating Large Language Models with metaverse platforms suggests how AI can facilitate immersive learning by creating learning scenarios in which users co-design educational activities through natural interaction with intelligent systems [17]. Text-to-image technologies represent a particularly significant innovation in urban co-design processes, as the ability to translate textual descriptions into immediate visualisations facilitates communication among stakeholders with varying technical skills. Integrating generative models with virtual reality environments allows users to collaboratively explore sustainable urban visions, transforming abstract ideas into visual prototypes that can be iteratively refined through collective feedback [23]. This approach overcomes traditional barriers to design, making visualisation processes previously limited to specialised professionals accessible to non-technical citizens.

Metaverse platforms and immersive environments . Metaverse platforms are shared virtual spaces that enable innovative forms of collaborative presence and shared manipulation of digital objects. Using the metaverse for participatory design offers persistent virtual environments that allow stakeholders to participate asynchronously in immersive co-design sessions [20]. This mode of virtual collaboration is not limited to replicating traditional workshops digitally. Still, it enables previously impossible forms of interaction, such as real-time collaborative manipulation of three-dimensional models and shared exploration of complex spatial scenarios. In this context, the realism of avatars and the management of authenticity become essential for building trust in virtual environments, without underestimating the significant challenges associated with user self-misrepresentation and the need to balance automation and human control in interactions [24].

Metaverse platforms such as Second Life or Spatial are emerging as places for participatory design in conservation and cultural contexts, where local communities can co-design digital representations of their cultural heritage, combining traditional knowledge with contemporary technological skills [25]. This application highlights the potential of the metaverse to preserve and revitalise cultural traditions, respecting cultural authenticity while embracing technological innovation. The persistence of virtual environments also enables the incremental construction of digital cultural artefacts through distributed, collaborative contributions over time.

Virtual reality and hybrid environments. Virtual reality environments offer levels of immersion that facilitate spatial awareness and presence, crucial elements for co-design processes that require a shared understanding of complex spatial contexts. Integrating virtual reality headsets with collaborative platforms allows participants to inhabit designed spaces virtually, experience the implications of design choices, and provide feedback based on direct sensory experiences rather than abstract representations [20] [26].

This mode of engagement transforms design evaluation from a cognitive process into a physical experience, potentially increasing the quality and relevance of participatory feedback and overcoming some limitations of pure virtual reality, while maintaining tangible connections to physical contexts and exploiting the expanded capabilities of virtuality.

Hybrid environments represent an emerging opportunity that combines physical and digital elements in hybrid experiences that maintain connections with the real world while exploiting the potential of virtuality. The implementation of collaborative design approaches that integrate language models with hybrid environments suggests that it is possible to create technological ecosystems that support multimodal modes of collaboration, combining gestural, vocal and textual inputs in fluid co-creation processes [27].

Integrated approaches and technological ecosystems. A significant application of co-design is the development and use of integrated technological ecosystems that combine diverse technologies within coherent, synergistic frameworks. The combined use of generative AI tools, metaverse platforms, and immersive environments creates application possibilities that exceed the sum of their individual components. Participatory design that integrates these technological ecosystems supports the involvement of non-specialist users in shaping and envisioning future scenarios [28].

This approach is also evident in the integration of decentralised technologies (such as Blockchain) with AI tools to create frameworks that promote participatory governance. This technological combination enables innovative forms of community empowerment that transcend traditional participation models, creating digital infrastructures that support community self-organisation and self-determination [29].

Process integration methods. The integration of technologies into co-design processes presents significant temporal and functional variations. Some applications integrate digital tools throughout the entire process, from problem definition to final evaluation, creating fully digitised workflows that leverage the capabilities of each technology at specific moments in the design process [20] [27]. Other approaches focus on the use of technology on specific phases, such as prototyping or artefact creation, while maintaining traditional methods for phases that benefit most from direct human interaction [22] [28].

The selection of the integration mode reflects strategic considerations about the areas where digital technologies offer the greatest added value in the collaborative process. Generative AI is particularly effective in the creative and ideation phases, where it can amplify divergent thinking and generate multiple alternatives.

Metaverse technologies show maximum value in the evaluation and refinement phases, where spatial presence, virtual experimentation and experiential feedback become crucial for informed design decisions.

Table 1. Summary table of areas of application and emerging approaches.

Technology / Approach	Main application Context	Function / Added Value in the Process	Main Benefits / Outcomes	References
Generative AI and Large Language Models (LLM)	• Value-Sensitive Design • Immersive Education • Urban Co-design	• Catalyst for collaborative processes. • Neutral mediator for structured dialogues on values. • Generator of scenarios and content (text-image).	• Integration of ethical considerations. • Facilitation of communication between technical and non-technical stakeholders. • Overcoming communication barriers through immediate visualisations.	Sadek et al., 2023; Noh & Narayan, 2025; Bussell et al., 2023
Metaverse Platforms and Persistent Virtual Environments	• Asynchronous participatory design • Cultural preservation and revitalisation	• Shared space for collaborative presence and manipulation of digital objects. • Platform for the co-creation of digital cultural artefacts.	• Enables interactions impossible in the physical world (e.g., collaborative 3D manipulation). • Incremental and persistent construction of knowledge and projects. • Preserves cultural authenticity while embracing innovation.	Ng et al., 2024a; Ramadan & Ramadan, 2025; Martins et al., 2022
Virtual Reality (VR) and Hybrid Environments	• Co-design of complex spatial contexts • Experiential project evaluation	• Facilitation of spatial awareness and presence. • Transformation of project evaluation from cognitive to physical experiential.	• High-quality participatory feedback based on direct sensory experience. • Maintains tangible connections with the physical context while expanding the possibilities of virtuality.	Ng et al., 2024a, 2024b; Xu et al., 2024
Integrated Technological Ecosystems	• Engagement of non-specialist users • Participatory governance and community empowerment	• Synergistic combination of generative AI, metaverse, and immersive environments. • Integration with decentralised	• Supports the collective visioning and construction of future scenarios. • Enables innovative models of community self-	Hohendanner et al., 2024; Calzada, 2024

		technologies (e.g., Blockchain).	organisation and self-determination.	
Process Integration Modes	• Strategic management of the design workflow	• Full integration: Use of technologies in all stages of the process. • Focused integration: Technological use concentrated on specific stages (e.g., ideation or prototyping).	• Maximises the added value of each technology in the most appropriate stage (e.g., LLM for ideation, Metaverse/VR for evaluation). • Flexibility in balancing automation and direct human interaction.	Ng et al., 2024a; Xu et al., 2024; Hohendanner et al., 2024; Sadek et al., 2023

Although representative of the state of the art, this mapping and the related summary table are inevitably incomplete. The dynamics of technological tools and methodological approach evolution are so rapid and constant that any attempt at systematisation is bound to be overtaken in a short time. It is therefore essential to view this work not as a definitive categorisation, but as a snapshot of a constantly changing landscape.

The relationship between these tools and design processes should be understood not as a one-way implementation, but as a two-way, co-evolutionary dialogue. Technologies do not merely influence design methodologies; they are shaped and redefined by the needs, critiques and creative practices that emerge from their use in real-world contexts. This symbiotic and dialectical relationship - this ongoing dialogue - drives innovation in design and technological development, requiring researchers to constantly update and critically rework existing frameworks. The challenge lies in creating open models to accommodate and interpret this ongoing transformation.

3 A design process for social innovation that integrates GenAI and the metaverse: the OSMOSI case study

The OSMOSI (Observation and Study of Models for the Design and Development of Hybrid Spaces) research-action project was created to study and experiment with the role of socio-cultural hybrid spaces as tools for urban regeneration, social inclusion and cultural innovation. The European Union has funded it through Next Generation EU and the PRIN 2022 fund of the Ministry of University and Research. It is coordinated by the Polimi DESIS Lab (Department of Design at the Politecnico di Milano), in collaboration with the Department of Architecture at the University of Palermo and other departments at both universities.

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Socio-cultural hybrid spaces combine cultural, social, educational and entrepreneurial functions [30]. They often occupy disused public or private buildings, such as factories, schools or convents. They address the problem of de-functionalisation affecting around 10% of Italian state-owned real estate and help revitalise local neighbourhoods and communities.

These spaces, which find economic sustainability through the combination of public and private resources, share common characteristics. They have a strong cultural identity, host artistic and social activities, offer multiple services, involve diverse audiences, experiment with new models of participatory governance, and promote accessibility and inclusion.

OSMOSI focuses on two Italian regions, Lombardy and Sicily. It analysed more than one hundred spaces through questionnaires and interviews. The data collected concerned the identity and history of the spaces, their size, context, value propositions, activities, accessibility, economic resources and characteristics of the built environment. The approach combined quantitative and qualitative data to obtain a complete picture. Alongside the mapping, two pilot projects were launched. Open Casello was created in Milano, housed in a former toll booth and promoted by the municipality with the support of BASE Milano and other organisations. It is an urban laboratory that supports youth networks and associations. In Palermo, the Museum of the Cities of the World opened in the former Convent of the Crociferi. It was granted temporary use to Farm Cultural Park as an intercultural platform and cultural production centre.

Fig. 1. Elements Open Casello façade (Milano) and interior of the former Convent of the Crociferi (Palermo) © OSMOSI Team.

The design process involved three phases. The first was the mapping phase, which combined a survey of 80 hybrid spaces (62 in Lombardy and 18 in Sicily) with 29 responses and 12 semi-structured interviews with space managers, municipal officials, and cultural operators, each lasting approximately 60 minutes. The second phase was dedicated to co-design with sessions focusing on interiors, community needs, services, accessibility and management strategies. Co-design activities included 6 workshops in Milan (20 high-profile participants selected from youth associations, municipal welfare and public property offices, and space managers who have participated in multiple workshops) and 5 (150 participants, including cultural, social and municipal operators and several groups of students) in Palermo, structured in an onboarding phase, facilitated discussions and co-creation activities. The third was the dissemination of results with the production of replicable guidelines and toolkits.

The phases also integrated AI and metaverse tools to optimise, expand, democratise, disseminate and customise the activities the research group designed and developed. Specifically, these include:

• metaverse: through the Spatial.io platform, workshops were held in the metaverse, aimed at experimentation by actors geographically distant from the pilot projects' physical locations and testing co-design methodologies in virtual reality. This experience created the OSMOSI digital area, which reconstructs Open Casello and the Museum of the Cities of the World in 3D. Users can visit these virtual spaces, leave comments, participate in discussions and co-create maps of possible uses.

• Interpretative Artificial Intelligence: in the OSMOSI project, Large Language Models (LLMs) were used as interpretative analysis tools to process the vast corpus of qualitative data collected. LLMs were used to support the synthesis of hundreds of pages of interview transcripts, workshop notes, and open-ended questionnaire responses. While a controlled comparison was not the aim of this study, the tool enabled faster iteration of thematic summaries, which were subsequently reviewed and corrected by researchers. The models were used to identify recurring themes, conceptual clusters and linguistic patterns that emerged from the different stakeholder communities. This automated analysis allowed researchers to quickly distil crucial insights into everyday needs, values, and critical issues, translating many subjective narratives into a matrix of codified, comparable project priorities. AI thus served as a powerful computational magnifying glass, not replacing human critical judgment, but complementing it to highlight connections and trends that would otherwise be difficult to grasp manually in such extensive and multifaceted datasets.

• Generative Artificial Intelligence: this was used in OSMOSI to translate the identity of each hybrid space into coherent visual materials for communication and dissemination. Starting from the textual and photographic documentation collected during the mapping process, text-to-image models were trained to recognise and reinterpret the characteristic elements of each place (colour scheme, architectural style, types of activities) (Fig. 2).

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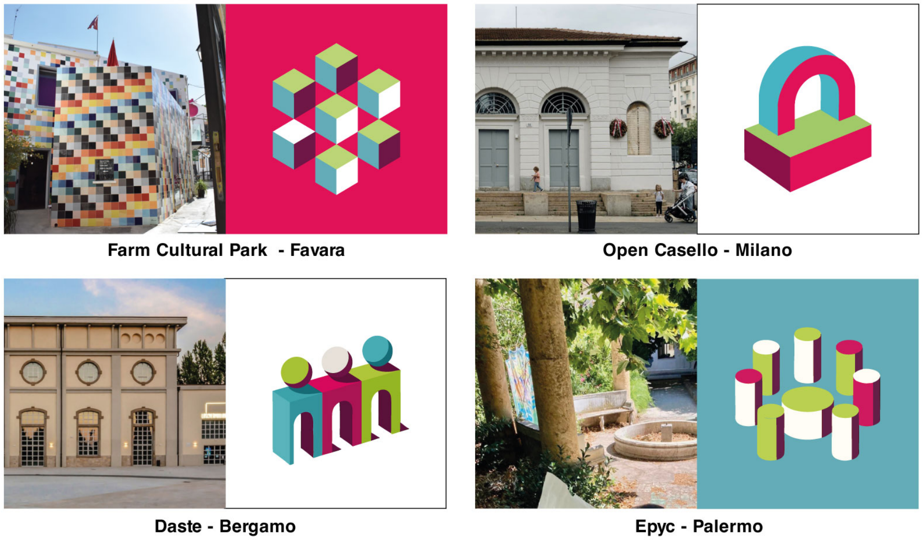

Fig. 2. Examples taken from the iconographic system created from a prompt that incorporates a description of the hybrid space, images of the space, and visual reference elements.

This process made it possible to autonomously generate visual communication materials - such as concept art, visualisations of future scenarios and icons - that maintained a strong link with the specific identity of the place, while being graphically uniform with the aesthetics of the OSMOSI project. The result is a hybrid visual code that makes the complexity of these spaces immediately recognisable and accessible to a broad audience, improving their narrative and perceptual accessibility without standardising their unique characteristics.

• Conversational Artificial Intelligence: OSMOSI has implemented a conversational AI system based on LLM to democratise access to the knowledge produced. This system acts as a natural language interface to the project database, allowing citizens, administrators or researchers to query the vast wealth of mapping data directly. Users can formulate complex queries (e.g., 'Which spaces in Sicily offer services for young people?') and receive concise, accurate answers dynamically extracted from the dataset. Since LLM responses can be incomplete or inaccurate, the interface is intended to support exploration and orientation rather than to replace direct consultation of underlying entries. Furthermore, leveraging the model's generative capabilities, the AI could compose short narrative podcasts and engaging descriptions for each space, transforming raw data into accessible storytelling. This approach transforms the dissemination of results from a static activity into an interactive, customisable dialogue, expanding the research's potential impact.

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4 A GenAI+Metaverse application protocol in co-design for social innovation

The OSMOSI action research project was created to explore the role of hybrid socio-cultural spaces as tools for urban regeneration, social inclusion and innovation. The complexity of this objective requires a methodological approach that integrates traditional research practices, advanced digital tools and innovative participatory processes. In this context, GenAI and the metaverse are two central elements of the operating protocol. The protocol visualisation shows how these tools are positioned along a flow of activities, divided into the three phases mentioned above (mapping, co-design, dissemination), that starts with the research group and ends with the OSMOSI web platform, designed as a space for accessing, disseminating, and sharing results (Fig. 3).

The following description illustrates how the protocol works, outlining the various steps and explaining how artificial intelligence and the metaverse support the collection, analysis, dissemination and co-design of activities.

The platform thus becomes a single point of access and interaction, connecting research, communities and institutions. In this way, the protocol helps collect and analyse information and creates a digital, participatory ecosystem that supports field action.

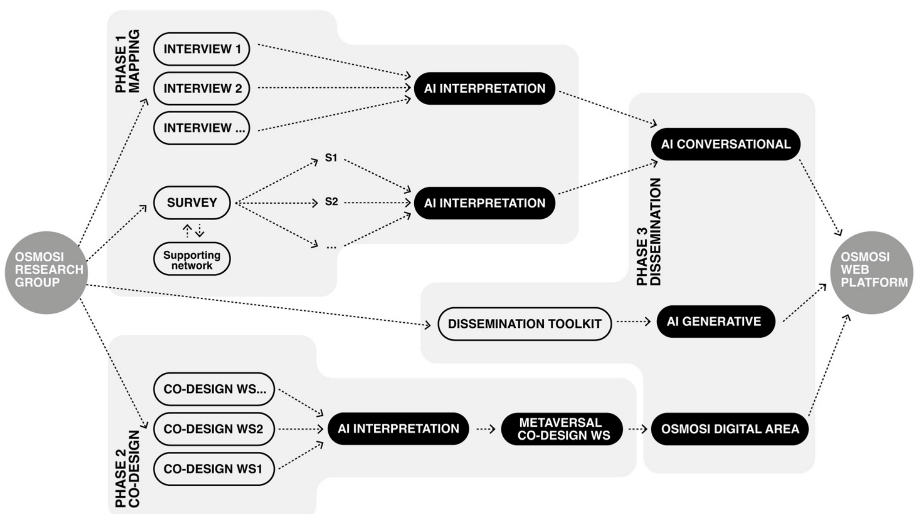

Fig. 3. Visualisation of the AI and metaverse application protocol in the OSMOSI design process.

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Data collection through interviews and surveys, and data interpretation using artificial intelligence modules. The first step of the protocol, the mapping step, is the collection of data from territorial contexts. The OSMOSI research group uses two primary tools. On the one hand, qualitative interviews are conducted with key players, including hybrid space managers, representatives of local institutions, and members of social innovation networks. On the other hand, a structured survey, optimised thanks to the project partners, is administered to collect information on a large number of hybrid spaces.

The interviews generate detailed narratives that highlight practices, critical issues, and strategic visions. The surveys produce quantitative, comparable data thanks to a questionnaire organised into sections covering identity, context, activities, accessibility, governance, and economic sustainability. Both tools are supported by a network of local and national partners who encourage the involvement of regional actors. The material collected through interviews and surveys is transferred to an artificial intelligence-based interpretation system. This module processes data systematically and consistently, reducing information fragmentation and identifying recurring patterns. AI applied to interviews focuses on semantic analysis and linguistic pattern recognition to extract key concepts and relationships among emerging themes. As for surveys, AI enables integration of numerical data and open-ended responses, generating correlation maps and trend indicators. In both cases, the use of AI reduces analysis time and produces summaries that maintain the complexity of the information. All the information obtained has been translated into a consultation map on the OSMOSI dissemination platform (Fig. 4).

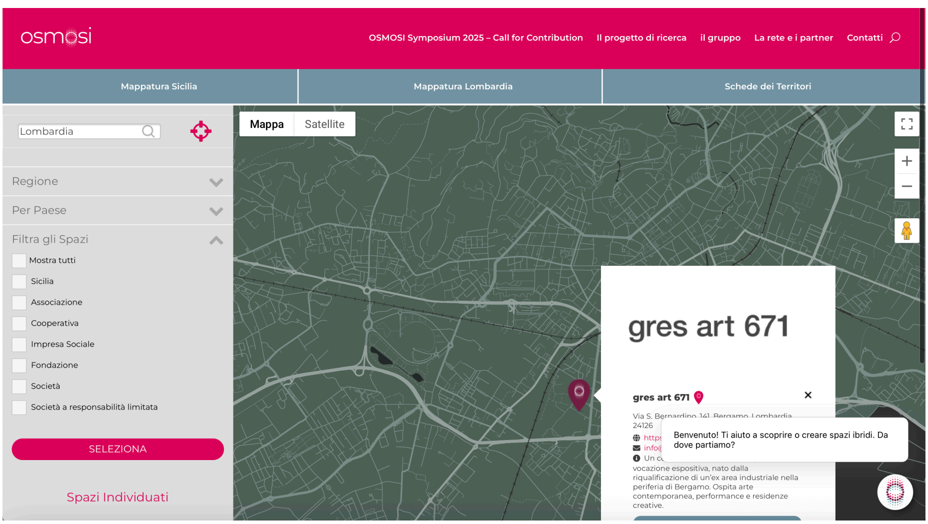

Fig. 4. Mapping consultation tool on the dissemination platform.

Transforming data into accessible interfaces. After interpretation, the results are made available through two other artificial intelligence applications: the conversational and generative components. The first consists of a conversational AI interface that allows users to query data using natural-language questions. This tool serves as a mediator between complex datasets and platform users, providing targeted answers and clear explanations. The aim is to make the research-generated information accessible to non-expert users, encouraging widespread use of the results. This has given rise to “OSMOSI Chatbot”, a chatbot active on the project website through the Fastbots service (Fig. 5), trained on the entire research and mapping of the project. The second application concerns generative AI. This is used to transform the data collected and interpreted into dissemination toolkits. AI produces applicable graphic materials that can be adopted by future hybrid spaces, local authorities, and cultural organisations to communicate their spaces and bring them into the OSMOSI network. In this way, AI is not limited to processing data but also contributes to the production of practical, replicable tools.

Example interactions:

(1) User: “Which services are most frequently requested by hybrid spaces in Sicily?” Chatbot: “According to data collected in the OSMOSI project, the most requested services from hybrid spaces in Sicily include: coworking, cultural events and activities, training, art exhibitions and displays, and content production. Are you interested in learning more about any specific services?” (2) User: “What is the annual income of a hybrid space?” Chatbot: “According to data collected in the OSMOSI project, the annual income of hybrid spaces can vary […] Would you like to know more about a specific case?

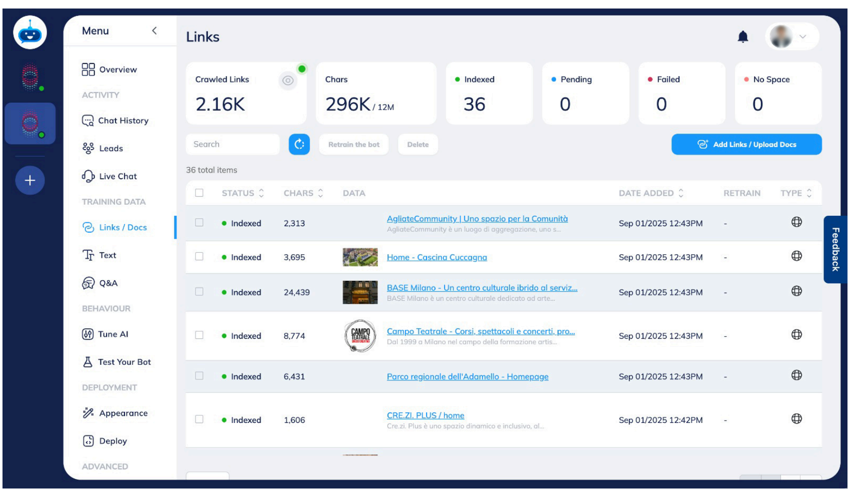

Fig. 5. OSMOSI chatbot configuration screen created using Fastbot.

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Co-design workshops as opportunities for participation and transposition of participatory processes into the metaverse. Alongside data analysis, the protocol provides for the organisation of co-design workshops. These workshops took place in the context of pilot projects, such as Open Casello in Milano and Museo delle Città del Mondo in Palermo. Citizens, institutions, cultural organisations and local stakeholders are involved in the workshops.

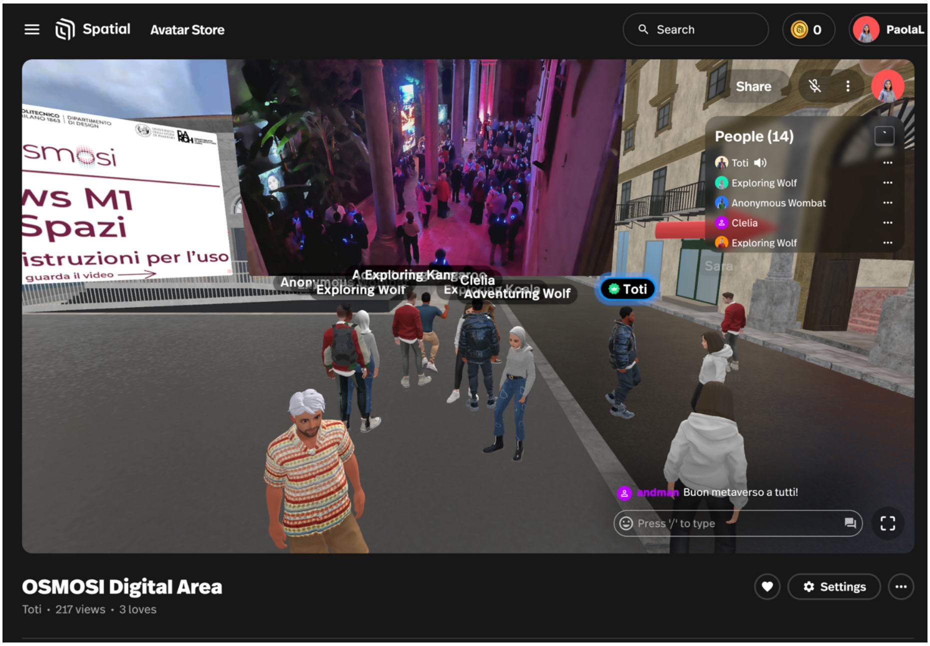

Fig. 6. OSMOSI Digital Area - https://www.spatial.io/s/OSMOSI-Digital-Area-675c1e2503c23ab5fd86f407?share=7225925571254868920

The meetings gathered ideas and proposals on community needs, services to be developed, management strategies and accessibility criteria. Here too, AI is used to interpret and systematise the contributions that emerge, reducing information dispersion and facilitating the identification of shared priorities. A significant part of the protocol concerns the transposition of co-design processes into the metaverse. The OSMOSI Digital Area (Fig. 6), a three-dimensional reconstruction of the two pilot projects, was created using the Spatial.io and Coderblock platforms. Here, users can move around as avatars, explore digital environments, read information panels, leave notes and participate in discussions. The distinctive features of the metaverse are the ability to overcome geographical and temporal constraints, access to multiple perspectives thanks to three-dimensional navigation, and the use of integrated tools such as collaborative whiteboards. This digital environment increases engagement, allowing even those who are distant or face logistical limitations to participate actively in the design process. Workshops in the metaverse follow a structured format. They begin with a technical and conceptual onboarding phase, continue with free exploration of the spaces, include guided discussion and co-creation activities on interactive maps, and conclude with an asynchronous feedback phase. This organisation allows for a high level of inclusion and a plurality of perspectives.

5 Discussion and conclusions

In a co-design process, artificial intelligence and the metaverse play distinct yet complementary roles. These tools share some common characteristics: they are designed to increase the accessibility of research processes, reduce barriers to entry, promote the replicability of models, and integrate contributions from different actors. The reflections developed in this article allow us to outline some general conclusions about their integration into co-design processes for social innovation.

Firstly, the protocol developed and tested in the OSMOSI project demonstrates that these technologies are not minor add-ons, but active players capable of structurally influencing collaborative design practices. AI, in its interpretative, generative and conversational forms, enables reprocessing complex data, sharing knowledge, and creating replicable operational tools. For its part, the metaverse opens immersive, inclusive spaces that overcome physical and temporal barriers, making participation accessible even to distant or traditionally excluded individuals. Their combination not only strengthens the capacity of participatory processes to include diverse voices but also contributes to the generation of new modes of experimentation [21]. At the same time, these tools introduce significant trade-offs that can threaten core qualities of participatory and co-design practice. Some aspects that may be lost or weakened include the role of LLM-mediated synthesis, which can further risk "flattening" plural narratives into coherent storylines, privileging what is most frequent or linguistically salient over what is most consequential. Similarly, metaverse-based workshops can amplify asymmetries between those who are comfortable with immersive interfaces and those who are not, and shift facilitation power towards whoever controls the platform, its configuration, and the rules of interaction.

Secondly, the activities tested suggest that hybridising analogue and digital tools is necessary to preserve the qualitative value of action research practices. Interviews, workshops and direct observations continue to play an irreplaceable role in stakeholder engagement and shared co-design. Still, they become more effective when supported by automated analysis and digital environments that amplify their dissemination and impact. In this sense, the proposed protocol does not replace traditional co-design processes. Still, it enhances them, paving the way for an “augmented” design paradigm that integrates design creativity, scientific rigour and technological capability. Exclusion risks must therefore be treated explicitly. Participation may be constrained by device availability, connectivity, accessibility needs (including sensory or motor constraints), language and literacy barriers, and discomfort or fatigue associated with immersive environments. In addition, the capacity to effectively “work with” AI tools can become a new form of expertise that is unevenly distributed. For these reasons, we frame AI and metaverse components as complements to, not replacements for, established participatory infrastructures. Furthermore, we support the adoption of measures to mitigate these risks of exclusion: multimodal participation options (virtual and in-person contact points), onboarding and facilitation, transparent documentation of AI use, and validation practices that preserve the traceability of digital activities to participants' opinions.

A third element concerns the redefinition of the role of the researcher and designer. Adopting AI and the metaverse means that researchers are no longer just observers and analysts, but also facilitators of complex processes and designers of digital tools that become an integral part of the design process [31]. This new role raises methodological issues, as it implies increased responsibilities in technological integration, process accessibility, and data protection. It is clear that participatory co-design for social innovation, when integrated with emerging technologies, must include stronger principles of inclusiveness, transparency and accountability.

The fourth point that emerged from the experience concerns replicability. The OSMOSI protocol, tested in Milano and Palermo, demonstrates that it is possible to develop methodological frameworks that can be transferred to other territories and cultures, while maintaining the flexibility to adapt to local specificities. This feature is crucial for envisaging the dissemination of operational models capable of supporting urban regeneration and cultural innovation processes in different contexts.

Finally, the reflection highlights three cross-cutting dimensions that remain open and require further exploration:

• the tension between automation and human control highlights how human control is essential to overcome the limitations of AI systems [32] and how balanced integration between AI and human facilitation can amplify the activities' effectiveness [33]. This tension suggests that the success of applications depends on the specific calibration of the automation-control mix rather than on universal solutions.

• The criticality of collaborative engagement emerges as a critical success factor where collaborative dynamics are the main driver of innovation [34] and social engagement. Collaborative sharing and co-design for inclusivity become essential

[35] and are better supported by AI-metaverse solutions that amplify human collaborative capabilities rather than replace them.

• The centrality of ethical and inclusivity considerations that highlight the importance of user-centred approaches, focusing on inclusivity, accessibility and security in digital environments. Design must consider user heterogeneity, differentiated digital skills and potential algorithmic biases that can amplify existing inequalities.

The integration of artificial intelligence, the metaverse, and co-design should therefore not be understood as a mere application of technological tools to an existing process, but as the construction of a design system capable of approaching participatory co-design from an integrated, strategic perspective. The protocol presented demonstrates that it is possible to combine participatory practices and advanced digital tools into a replicable model useful not only for the scientific community but also for public administrations, policymakers, and local actors. The future challenge will be to consolidate this model, critically evaluate its impacts, limitations, and opportunities, and transform it into a stable resource to facilitate social innovation processes.

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