Publishing Series in PROJECT | Essays and Researches
On Sustainable Built Environment
between Connections and Greenery
vol. 07 | 2022 | paper 16 | pp. 288-305

ISSN (print): 2704-6087
ISSN (online): 2704-615X
ISBN (print): 978-88-5509-445-0
ISBN (online): 978-88-5509-446-7

DIGITAL DESIGN, TECHNOLOGY AND SUSTAINABLE IMPACT
From apparent contradiction to strong coalition

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section
DESIGN

typology
RESEARCH & EXPERIMENTATION

DOI
doi.org/10.19229/978-88-5509-446-7/7162022

ABSTRACT
Design, through its ability to predict future scenarios, has the role of meeting the challenges posed by current digitization in relation to the apparent dichotomy with the sustainable dimension. This aspect is explored in the article through the analysis of the SMAG and COLUX projects. The first develops a product-service system equipped with an advanced technological set-up capable of controlling the vital parameters of green spaces. The second designs an innovative platform for creating virtual environments for co-designing products and living spaces using AR and VR. The main focus of the projects concerns the innovation of the design/management process in real time of the services through direct comparison with the actors involved in a perspective of environmental, economic and social sustainability. Such research emphasizes the importance of the repercussions of digitization and the role of design in a 'digicircular' transformation framework aimed at increasingly sustainable practices.

KEYWORDS
digital sustainability, smart system, co-design, collaborative platform, service design

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The forced distance, the forced absence of human relationships and the economic-social hardships resulting from these years of the pandemic have made it clear, now more than ever, that we are part of a community with a common destiny and that everyone is responsible for each other in this system based on reciprocity that gives rise to an intertwined network where each node contributes to the sustenance of the others, consequently leading to the achievement of systemic and collective well-being. The condition of isolation that we had to endure 'took our breath away', but nevertheless gave 'relief' to our planet (Dellink et alii, 2021). All this can do nothing but place us in front of the evidence that our presence, voluntarily and involuntarily, is guilty of numerous and serious damages to our ecosystem. During the two months of isolation, we were able to witness the phenomenon of re-appropriation of space by the natural ecosystem, which thus highlighted how the absence of human disturbance represents a positive aspect for the surrounding environment.

This consideration leads to rethinking the acts conducted at the expense of the natural environment and regaining a regenerating contact with it. If plants are the only living entities capable of naturally producing oxygen, it is obvious to think that their presence in the world – as well as having to become ever greater – will lead to greater human well-being. So nature, and particularly the relationship through which we live in contact with it, will have to be the starting point for any project or political action (United Nations, 2015). It is precisely from this need to restructure a new relationship with nature that the research project SMAG – Smart Garden was born, developed to improve the management of green spaces within cities and domestic spaces by trying, through the use of advanced technologies, to make humans communicate with their plant surroundings by giving 'voice' – in the true sense of the term – to plants.

From this project in which the research group of the Laboratory of Design for Sustainability of the University of Florence (Department of Architecture) was able to experiment with the potential that digital technologies have, if used consciously, to produce strong effects in environmental terms, the idea was born to try to experience how the same approach could also adapt well to relational dynamics between people, especially in the workplace. The COLUX (CO-design platform using Mixed Reality for the LUXury interiors sector) research project is based on this last reflection, which develops starting from people's needs to structure new channels for communicating, creating digital and virtual workspaces aimed precisely at sharing and co-designing. The two projects – presented in detail in the following paragraphs – thus aim to explore how it is possible to develop a future design that, exploiting the application of contemporary innovative technologies, helps to facilitate the dialogue between the actors present in our ecosystem, in the double relationship of Human-Nature and Human-Human.

In both projects, an element of analysis that was extensively covered was the application of high-tech solutions to solve the starting problem. Indeed, rapid technological development and the increasingly totalitarian presence of digital solutions lead us even more often to identify, in some cases erroneously, innovation with the technology

itself. This becomes a fundamental piece of the innovation process in all sectors. In reality, Digital Transformation, while having the power to change the meaning of things (Epifani, 2020), needs to cultivate a strategic vision of systems and scenarios that can only be realized through the application of a creative process. Designers, thanks to their ability to see, show, predict (Zurlo, 2012) and plan the future, thus have in this context the role of taking the challenges posed by digital evolution and translating them into concrete systemic actions. Developing digital projects means developing strategic projects that exploit technology as a tool to support the result, and which must therefore be based – to have an effective scientific value – on a whole series of methodologies and processes that have been refined over the years, such as User Experience Design, Service Design, Co-Design, and Design Thinking.

In addition, in both projects, the issue related to the use of digital technologies by the end user emerged strongly. Telematic technologies today certainly make it possible to greatly reduce the organizational congestion of daily life, reducing travel to workplaces, shopping malls, banks, etc., thus ensuring the possibility of using a service in a 'remote' mode.

But when do people use a digital system or service? And again, when are the technological innovations we use really in line with our daily or work activities? Are we, perhaps, simply 'forced' to use them? We have tried to answer these questions through the projects presented, precisely moving from the desire to develop in each of them new ways related to interaction with green spaces and work. In the future, strongly useful as well as innovative services can be designed, contributing consciously and strategically to a development process that will be inevitable as well as unavoidable. An example can be found in Senseable City, where the replacement of the term smart highlights the need to consider technology precisely as a medium of the relationship between inhabitants and space, understood as a hybrid entity at once physical and digital (Ratti and Claudel, 2018). Data are then considered as a real device of interaction between the aforementioned superstructure and users/citizens, understood both as users of services, but also as actors of them and especially as 'human capital of knowledge (OECD, 2007) useful for their design' (Formia, Ginocchini and Ascari, 2021).

The integration of users as co-producers in local, national, and European service and policy development processes is also required today at the institutional level, as evidenced, for example, by the European Green Deal (European Commission, 2019). For this reason, it is fair to say that such integration must necessarily be one of the fundamental steps (picking up from participatory or Co-design methods) for any project development methodology to be implemented, especially when the project output is a highly technological or digital product or service. The role of fostering forms of human-centred development is therefore recognized to the culture of the project, as hoped for at the beginning of the formation of the New European Bauhaus (von der Leyen, 2020). Thus, we understand the relevance of the reasoning and the importance of deepening the evolution of the relationship between data, environment, design and

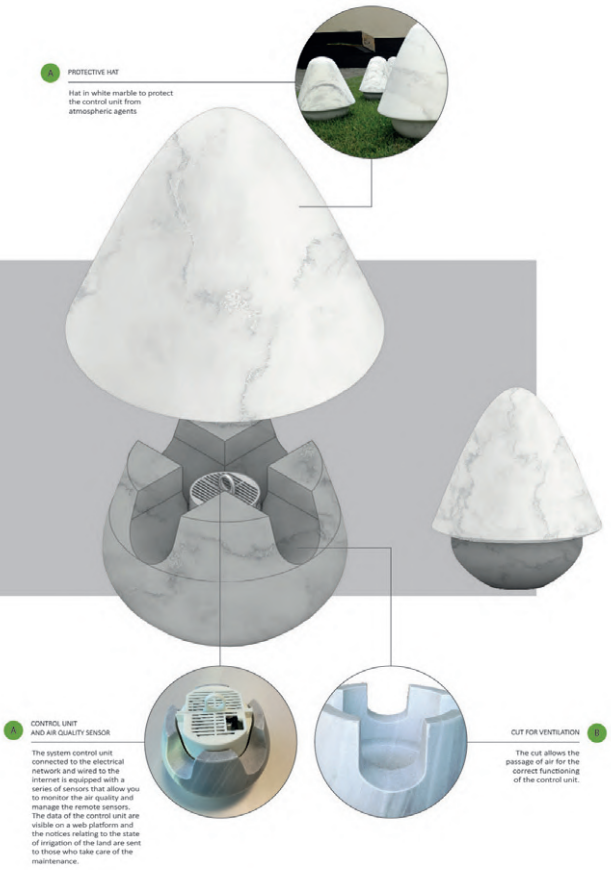
Fig. 1 | Smart System (credit: I. Fiesoli, 2018).

people for the conception of services aimed at the development of an ecosystem (including production) of the future, oriented toward social, as well as environmental and economic, sustainability (Formia, Ginocchini and Ascari, 2021; Fig. 1).

SMAG: the Smart Garden of the future | According to Socco et alii (2005), parks and green spaces are essential elements for the livability of cities; their quantitative increase and qualitative improvement are indicators of a city that cares about the quality of life of its inhabitants. However, the management of green spaces in urban contexts causes significant inconveniences that can be mitigated by ensuring an adequate supply of services for parks and gardens. The preservation and proper maintenance of the network of green spaces that populate cities, as well as many homes, create new environments in which people express a desire to live by fostering and ensuring the regeneration of the ecosystem itself. Good city management, therefore, cannot transcend its 'green' heritage and, above all, cannot disregard its nature as an ecosystem, that is, as an entity that the city environment absolutely needs to ensure the healthiest possible lifestyle for its inhabitants.

It is precisely from this need, which is now unavoidable, that the concept of the smart city (or smart city[1]) was born, based on a range of digital tools that can be used in urban settings. This solution opens the eye to new frontiers in the study of urban systems but at the same time generates new obstacles to understanding the real reasons behind the human need to live in cities. A particular ambivalence this one that leads people to want to live in contact with nature but without necessarily moving to the countryside, even though there is a trend away from large cities toward contexts with intermediate densities – small towns and suburbs (Istat, 2021) – making it even more important to protect the green spaces found in urban areas and our homes.

It is precisely on this assumption that the SMAG (Smart Garden) project was born (financed by the Tuscany Region within the RSI – POR FESR 2014-20 calls), which envisages the realization of a multi-sensor system for the detection of the main characteristics of a 'garden environment': thanks to the setting of the main parameters both



Figg. 2-4 | 'I Sette Nani' project by UpGroup, SMAG project (credit: A. Tanzini, 2020).

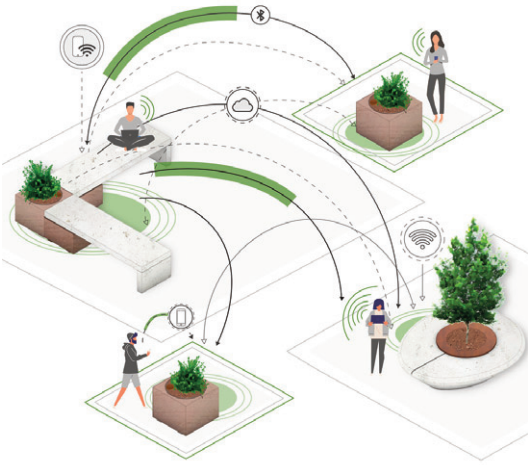
environmental and functional, it is able to implement strategies for the qualification of such environments by those involved in their maintenance, becoming a professional tool of support for companies operating in the efficient and optimized management of public and private garden areas.

From a technical point of view, the project leads to the development of a system of sensors and actuators placed inside furniture that, once positioned at particular points in the garden, are able to send data to a platform via a control unit. This management platform collects data from the control unit, records it, and analyzes it through advanced algorithms, creating a link between the garden's performance and the entity managing its maintenance, enabling predictive management of maintenance issues and consequently increasing the level of well-being and comfort of people and plants.

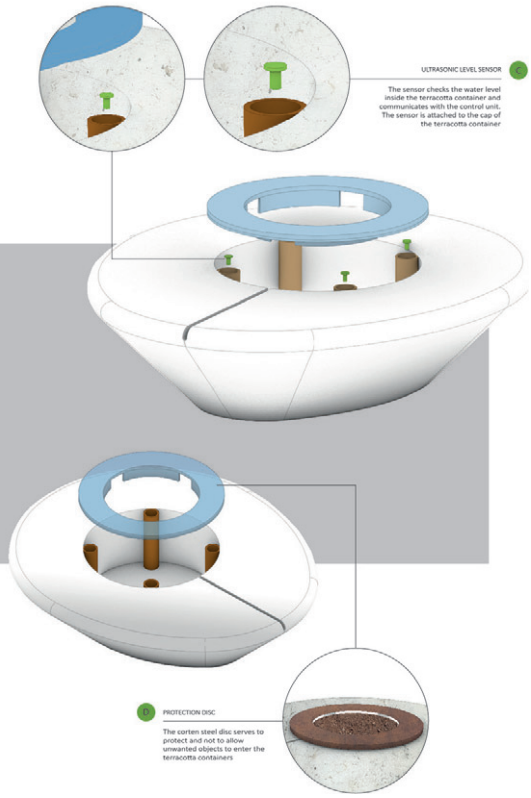
The challenge of the project was to use advanced sensors to attempt to detect the different aspects that can be monitored within a garden, such as: external environmental conditions (temperature, humidity, pressure, CO_2, particulate matter); soil conditions (moisture, density, PH, organoleptic composition); plant conditions (growth status, presence of problematic elements such as insects, poor plant structure); remotely accessible information, images, noise; and implementation of actions through electronic actuator apparatuses (irrigation, soil or plant nutrition, etc.).

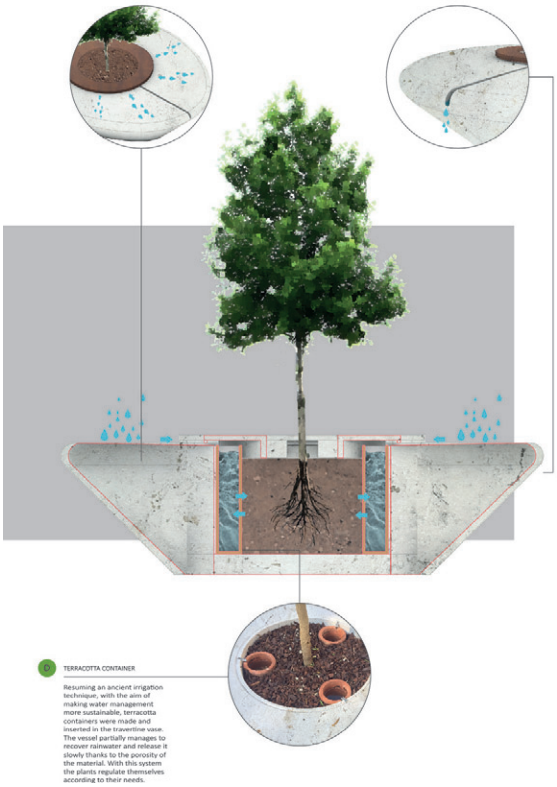
In particular, in the SMAG project these specific sensors are included in design products such as stone outdoor furniture systems and furnishings, produced by Travertino Sant'Andrea and UpGroup: I Sette Nani (in marble) is a collection of products designed for the private sector, in which each dwarf has a specific control and detection function (Figg. 2-4). Water Value and Litus (in travertine), on the other hand, are a series of urban design seats/pots and develop a system that reclaims ancient irrigation techniques, which involve capillary irrigation using terracotta jars placed inside a pot. At the top end of the jars, there is an ultrasonic sensor, connected to the rest of the system, capable of monitoring the quality of water available. If necessary, it alerts the garden manager or activates a valve that fills the pot directly from the water system connected to the pot (Figg. 5-9).

In addition, the SMAG project develops a system of sensors and actuators that send data to a specific platform through a control panel, based on various wireless and wired access technologies. The management platform collects data from the control panel, records it and analyses it through advanced algorithms. These detect the performance of the monitored green areas to manage, in a predictive and systematic way, the issues of maintenance processes of these spaces, whether public or private. Through this app, connected to the control panel, the different products actually become smart and are able to relate to the different actors who interact with the system: on the one hand, with the maintainer for aspects that concern the health and maintenance of green areas, and on the other hand, with people from an emotional/experiential point of view, raising awareness about green areas and how that particular place contributes to the improvement of our ecosystem (Marseglia, 2020; Fig. 10).




SOIL MOISTURE SENSOR
The WATERMARK is designed to be a permanent sensor, placed in the soil to be monitored and "read" as often as necessary with a portable or stationary device.
CONTROL UNIT AND AIR QUALITY SENSOR
The system control unit connected to the electrical network and wired to the internet is equipped with a series of sensors that allow you to monitor the air quality and manage the remote sensors. The data of the control unit are visible on a web platform and the notices relating to the state of irrigation of the land are sent to those who take care of the maintenance.


ULTRASONIC LEVEL SENSOR
The sensor checks the water level inside the terracotta container and communicates with the control unit. The sensor is attached to the cap of the terracotta container
PROTECTION DISC
The corten steel disc serves to protect and not to allow unwanted objects to enter the terracotta containers


TERRACOTTA CONTAINER
Resuming an ancient irrigation technique, with the aim of making water management more sustainable, terracotta containers were made and inserted in the travertine vase. The vessel partially manages to recover rainwater and release it slowly thanks to the porosity of the material. With this system the plants regulate themselves according to their needs.

Figg. 5-9 | ‘Water Value’ and ‘Litus’ projects by Travertino Sant’Andrea, SMAG project (credit: A. Tanzini, 2020).

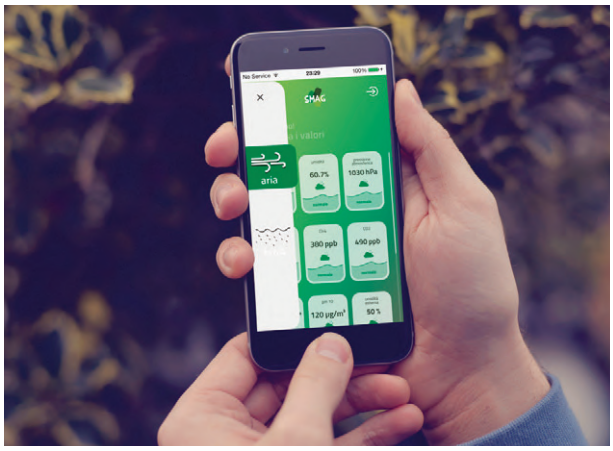


Fig. 10 | Platform interface project, SMAG project (credit: M. Sottani, 2020).

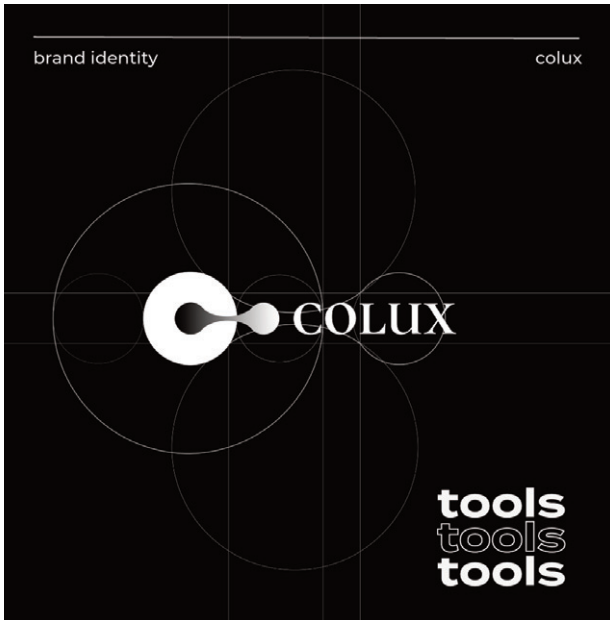


Fig. 11 | Constructive brand, COLUX project (credit: M. Costa 2022).

COLUX: a sustainable collaborative platform | Today, more than ever, companies are facing increasingly complex challenges arising from growing contemporary criticalities (Polifroni, 2021). Currently, in fact, as a result of the health emergency, traditional manufacturing companies base their competitiveness not only on the quality level of production – which by its nature characterizes them – but also on the ability to add further value to the product through the ability to respond immediately and ductily to increasingly demanding and customizable market demands. In this perspective, the digital evolution we are witnessing can contribute to a territorial development aimed

at economic, social and environmental sustainability in which the world of design and production is rethought by unhinging some inefficient contemporary paradigms.

In this moment of evolution and change, digitization can therefore offer an innovative approach that can transform the limitations that the pandemic has set us into challenging design opportunities through which local realities can explore new ways of working (Covato, 2020) and managing resources by rethinking and redesigning even environmentally harmful processes (Franco and Nuccio, 2021). At the same time, such integrated services also stem from the problems encountered in the logistical difficulties of manufacturing companies, in the movement of goods, increased production costs, reduced labour capacity, increased difficulty in sourcing raw materials and delivering products, to the new ways of smart working that still show shortcomings.

From this perspective, therefore, the ability to develop integrated systems such as co-design and management platforms represent a futuristic scenario capable of responding to such needs and obtaining positive responses in relation to the entire territorial and actor ecosystem. These solutions are highly innovative not only for the end users who benefit from immediate and personalized responses but also for the business and planning teams who are thus able to relate directly with the recipients, breaking down all kinds of geographical, temporal, and communicative barriers. To this end, in recent decades, increasing attention has been paid to the accessibility of digital tools, which must be able to connect a wide pool of users (designers, companies, stakeholders, and end users) by ensuring ease of language and visualization thus eliminating language barriers and enabling successful co-design practices (Pihkala and Karasti, 2018; Venkat Ramaswamy, 2004).

In the field of design and manufacturing, objects and spaces are usually presented to end users through technical drawings, sketches, renderings that are difficult for end users to understand and/or prototypes that produce a strong environmental impact. For this reason, the scientific literature is increasingly focusing on new interactive modalities – such as augmented reality and virtual reality - enjoying great success in the market (Zhang et alii, 2020; Wang and Schnabel, 2008; Rossato and Raco, 2017). The real elements of innovation are to be found in the application of advanced features that aim to create hybrid platforms and workspaces suitable for virtual sharing and connecting spatial realities. Designers and end users can then conceive shared projects and co-designed tailored solutions thanks to the ease of communication provided by these advanced technologies.

This type of innovative platform offers a comprehensive service ranging from storytelling to sales, after-sales and management control of resources thanks to which it is possible to give satisfactory answers to the many current needs, triggering attractiveness and customer loyalty. Digital co-design is, therefore, one of the most suitable enabling technologies for Factory 4.0 that can ensure benefits throughout the entire development of product/process/factory life cycle (Urban, Krawczyk-Dembicka and Łukaszewicz, 2022). The resulting sustainability must also be understood from a social

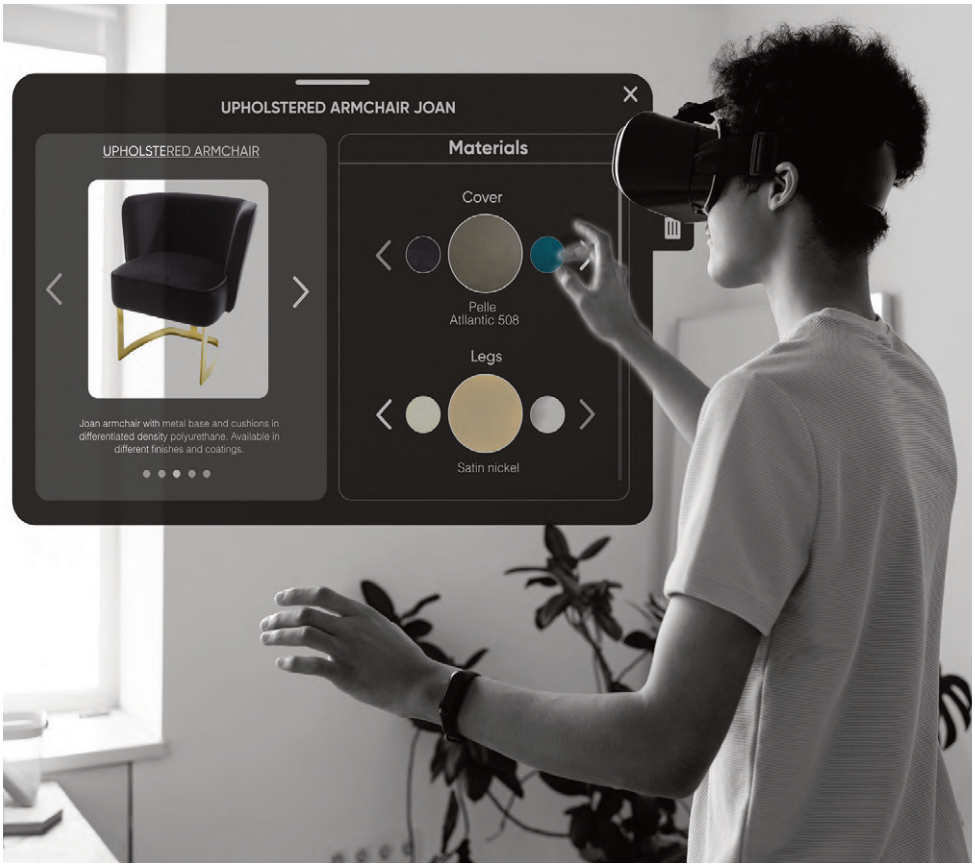


Fig. 12 | VR Application interface, COLUX project (credit: M. Sottani 2022).

point of view, through the improvement of the end-user experience and the inclusiveness and involvement in product conception/design.

Within this context, the COLUX project – CO-design platform using Mixed Reality for the LUXury interiors sector (Project financed under the Second Call POR FESR 2014-2020, Tuscany Region) explores the potential of new technologies, applied to the practice of co-design (Fig. 11). Indeed, the project aims at the creation of a creative, virtual and collaborative space; supported by the development of an innovative digital platform where different designers can collaborate simultaneously on the project through the use of interactive AR and VR technologies leading to the creation of digital spaces for the co-design of products and living environments (Fig. 12).

The project aims to facilitate 'remote' working practices by redesigning workspaces – especially related to the world of design and manufacturing – in a virtual mode, creating a metaverse in which to develop all stages of the creative process in real-time by

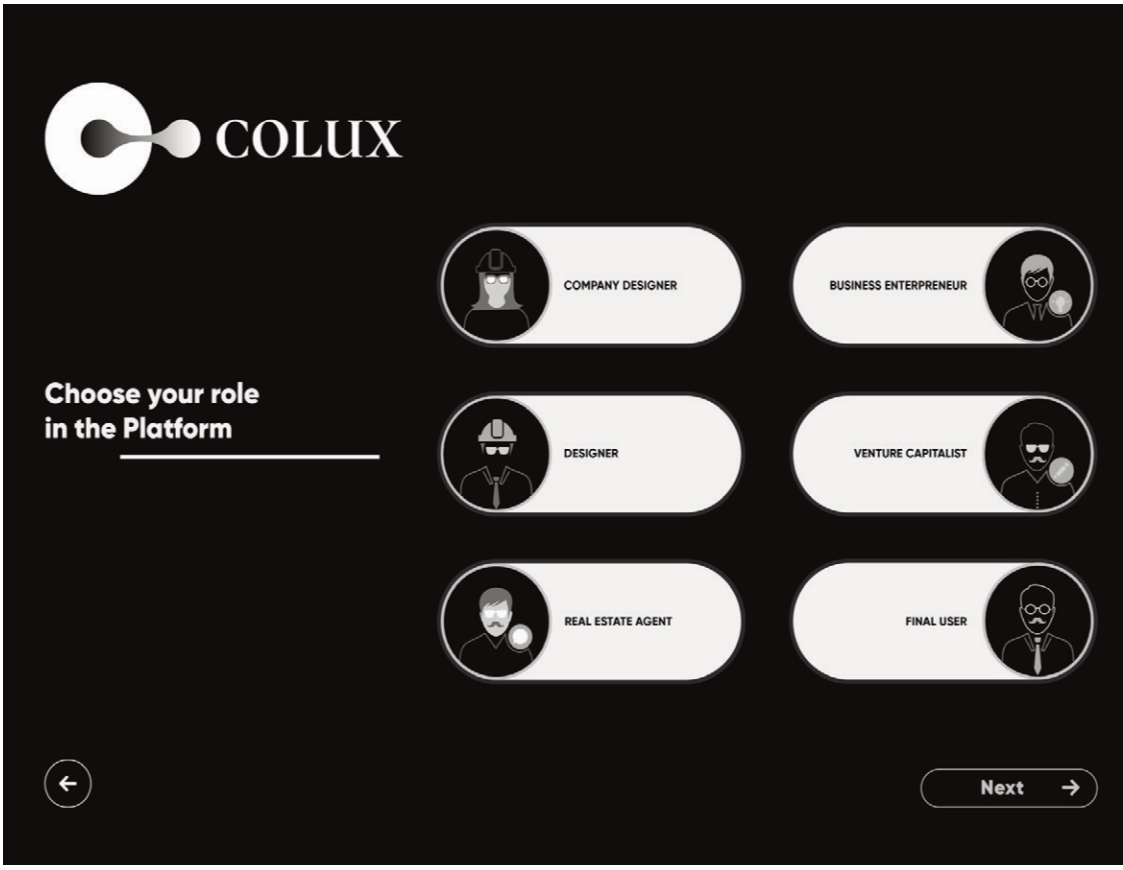


Fig. 13 | Multi-user function interface, COLUX project (credit: M. Sottani 2022).

involving the various actors. The overall system of this project works by connecting several professionals in real-time in a shared virtual workspace: a direct and fast channel that can exchange information on design project development (Fig. 13).

The work plan represents the continuum of a previous project – MixedRinteriors – which led to the definition of a virtual design asset for Unity software that enables the development of experiential builds, as well as products and environments, aimed at involving the end-user. Building on these design premises and experiences, COLUX focuses on enabling the user to view the designed space and product by interacting with it, viewing the details, modifying them, and (re)designing them carefully.

The platform allows you to create a close relationship with designers and end customers to offer high-value products accompanied by a high degree of customization and a wide range of services. The user can directly leave comments or make small changes by understanding the problems of the project, seeing the details, and creating

Fig. 14 | Interface for asset customization, COLUX project (credit: I. Fiesoli 2022).

a 'smooth' transition between the preliminary design phase and the subsequent executive realization. In addition, the visualization of design products and designed spaces generates a virtual catalogue that the project community can access by taking advantage of the development processes in an experimental and innovative way (Fig. 14).

From a social point of view, the community can indeed act on the platform through direct responsibilities, feeling part of a unique system. There are also no differences in terms of age, profession, type of organization, etc. Thus, there is no single user: the strength lies in the plurality of actors that populate it. This aspect, guaranteed by the simplification of technical language, is also reflected in the collaboration between designer and end user, and triggers important innovation processes on the social level as well.

All stages of the creative process thus involve the various actors with the aim, among others, of optimizing project time and costs. In light of the current environmental crisis, we are presented with a key opportunity to stimulate the reduction of resource consumption and increased awareness of ecological quality and well-being of the en-

tire territorial ecosystem. Indeed, the virtual space of the platform avoids 'waste' by reducing the waste elements associated with the physical production of prototypes, while maintaining the possibility of digitally verifying all the technical and design elements necessary for the development of a good project. COLUX sustainability also takes into consideration the reduction of environmental impacts related to communication and especially to the exchange of data (emails, photos, reports) through the actors of the creative supply chain (designers, architects, planners, engineers, technicians, entrepreneurs, sellers and end users).

The real-time display of different digital solutions, the exchange of data, their relative storage, and the analysis of any related issues are thus a challenge of the present times for a finally sustainable digital.

Implications, conclusions and future developments | The current environmental and pandemic challenges require the project to assume a key role in experimenting with innovative solutions to achieve the goals of ecological, economic and social sustainability. With this in mind, the modus operandi of the project must therefore include, among other aspects, a focus on supporting local and collective actions of land transformation and management on multiple levels of socio-cultural, typological and environmental complexity (Errante, 2021) from which the related implications derive.

The projects described in this paper are innovative due to their sustainable effects, where the term 'sustainability' must be understood in its broadest sense, encompassing environmental as well as economic and social perspectives. Specifically, within the SMAG project, in addition to the obvious repercussions in terms of environmental sustainability – given the very nature of the project – it is important to emphasize that there are also those related to economic and social sustainability.

If the economic implications appear obvious from the point of view of saving money and time for public administrations thanks to the programmed maintenance of green spaces in a customized and targeted way according to the 'manifested' need detected by the sensors on the platform; equally fundamental are the spin-offs in terms of social sustainability. In this perspective, it should be pointed out that users are active components of the digital system since by 'living' the space they will be able to send detailed feedback on the plant state, contributing both to its maintenance, to the co-design of the service and the implementation of its functionalities. This kind of participatory approach will also ensure greater awareness on the part of users/citizens, becoming a stimulus for the development of a renewed civic sense that is environmentally conscious and thus aimed at more sustainable practices.

In parallel, the COLUX project shows its spin-offs in terms of social sustainability, through improved end-user experience, inclusiveness and involvement in product conception/design. In this perspective, the research project plays a strong innovative role: compared to platforms currently developed and released in the market, COLUX creates a collaborative and inclusive platform model with a non-hierarchical social structure,

where each member is part of a community dedicated to design. COLUX also reflects the principles of economic and environmental sustainability through the reduction of costs and time associated with both the reduction of physical meetings and the transport and movement of stakeholders and business prototypes. The product customization is meeting the customer requirements through digital changes made in real-time that allows participants to connect from around the world, reducing unnecessary physical meetings and halving design time and costs as well as the cost of time to market.

From these project assumptions, it is clear that the idea is to start from the micro-scale of territorial levels (regions and municipalities) to try to activate concrete projects that are more controllable and manageable but equally lead to an improvement in terms of environmental sustainability, well-being for people's lives and management of businesses and, more generally, of infrastructure. On these three strands of development, it is safe to assume that, starting precisely from this sort of transcalar territorial acupuncture, improvements can gradually be made to the overall system, considered as a macro-area of intervention for the overall goal to be achieved.

In this sense, the projects analysed take an innovative approach aimed at experimenting with new paradigms capable of developing digital solutions – required by the contemporary world – that are compatible with the environmental and social needs of the territories in which they are applied and tested, as well as of the users. In particular, the presented projects become a direct strategic channel for the exchange of information on design project development (COLUX) or green space management (SMAG).

The benefits derived from the proposed solutions represent the influence of virtuous design on the development and management of digital processes capable of achieving positive effects on the entire territorial and social ecosystem, thus overcoming the apparent dichotomy between the terms 'digital' and 'sustainable'. The territorial spillovers of the case studies are thus to be understood in light of their design capacity to create replicable and scalable best practices. In fact, both projects enable the exploitation of digital tools for the creation of a conscious, sustainable, circular, inclusive and active supply chain by emphasizing how the digital and physical scenarios can concretely interface with each other.

In the case of the COLUX project, the beauty, knowledge and 'philosophy' typical of the chosen territory are shared globally, creating working connections through the use of innovative technologies that support the growth of manufacturing companies in terms of sustainability. In the case of the SMAG project, on the other hand, technology contributes to the control of the vital parameters of green spaces, supporting a product/service system capable of reformulating its management in terms of quality offered and capacity for innovation.

Scientific impact is to be understood in reference to the approach used in the two case studies, which, although with different results, brings out the opportunity to experiment with new combinations that aim to use digital tools to develop sustainable projects and to make the community more inclusive and aware. From a theoretical

point of view, the methodology used in the two case studies, linked to the needs arising from specific real needs and the resolution of related spatial issues, represents a high degree of reproducibility and scalability in other international scientific contexts.

Finally, from the reading of the projects presented, it is possible to consider their future potential and limitations. Both kinds of research, based on the relationship between digitization, sustainability, and community, constitute a driver toward the creation of future digital scenarios capable of focusing on the sharing of civic values concerning environmental heritage.

The limits of these design approaches, however, are to be understood both at the level of effective environmental sustainability and at the level of a lack of community education in digital innovation. From the first point of view, the difficulties are to be found, among others, in reference to the complexity of the relationship between growing contemporary digitization, fuelled by large amounts of hard-to-store data (i.g. big data), and the parallel need to streamline these volumes to reduce emissions. In the not-too-distant future, we will likely be talking about the digital waste that needs to be disposed of and data centres that can no longer maintain the entire digital infrastructure. At this point already at the present, it is necessary to adopt a tangible evaluation system that analyses the actual benefits derived from digitization in terms of customization and material waste reduction to examine whether such design applications can be sustainable in the long term.

At the same time, from a social perspective, there is an emerging lack of real awareness related to the use of digital technologies that addresses its limitations and potential even before its adoption. The negative effects of the unconscious use of such digital tools also need to be explored and debated with special reference to the well-being of the end user. Starting from these assumptions, these environmental and social aspects, which have not yet been analysed in COLUX and SMAG, represent both the limit of research and the opportunity on which to build future planning.

It is, therefore, necessary to activate a community digitization education process that is able to provide the tools to understand how to make the best use of technology in the professional and personal spheres, especially with a view to conscious and sustainable consumption. From the design point of view, it also becomes essential to analyse the effects of the psycho-physical well-being of the recipients, already starting with the accurate analysis of their user experience and the effect of the growing loss of physical dimension resulting from the increase of such digitization. Moreover, these approaches, typically linked to design, can also be applicable in other design areas (such as architecture and urban planning) to strengthen the spillovers of such choices in an ecosystem as broad as possible.

In this sense, unexpected scenarios capable of holding together technological experimentation, ecological repercussions and social innovation can develop through an exegetical attitude that aims to interpret constant and renewed social, economic and environmental needs.

Acknowledgements

The contribution is the result of a common reflection of the Authors. Nevertheless, the introductive paragraph and 'SMAG: the Smart Garden of the future' are to be attributed to I. Fiesoli, the paragraphs 'COLUX: a sustainable collaborative platform' and 'Implications, conclusions and future developments' are to be attributed to E. D'Ascenzi.

Note

1) For more information, see the web page: ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en

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Printed in
September 2022
by Fotograph s.r.l | Palermo

Editing and typesetting: DEMETRA Ce.Ri.Med. on behalf of NDF
Book cover design: Cesare Sposito