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# THE MIXED VIRTUAL/REAL MATRIX FOR WORKSPACES: A MEDIATING SOLUTION BETWEEN REMOTE AND ON-SITE WORKING

**Gabriel Tudora[1], Ana-Cristina Tudora [1], Florina Pantilimonescu[2], Raul-Andrei Saucă[2]**

[1]"Gheorghe Asachi" Technical University of Iasi-Romania, Faculty of Architecture "G.M. Cantacuzino",
Blvd. Mangeron, No. 59A, 700050, Iasi, Romania
[2]"Ion Mincu" University of Architecture and Urbanism, Faculty of Architecture,
Str. Academiei 18-20, 010014, Bucharest, Romania

Corresponding author: Florina Pantilimonescu, florina.pantilimonescu@gmail.com

***Abstract:*** One of the positive aspects of the pandemic has been the opportunity for people to experiment with an existing but untapped type of work: working online from home or from their favourite places or spaces. The ability to work from anywhere has made this an increasingly sought-after feature these days. Remote working presents a number of problems both psychologically and in terms of employee productivity and efficiency. These cannot be solved by the current limited solutions. This article attempts to provide a solution both to preserve the possibility to work from anywhere and to mitigate the undesirable effects of this way of working by implementing mixed real/virtual matrix and Smart Multimedia walls technology. The proposed solution aims at more than just making larger monitors. Through the technology proposed for use, it creates a space where people working remotely can interact as if they were in the same room, in an authentic office atmosphere. Many of the mental, efficiency and productivity problems can be solved by these shared, supervised and organised workspaces. The study is focused on defining a space for working and its constructive elements, designed to satisfy the needs observed in the meta-analyses phase. One major objective of the solution is to make use of Smart Multimedia Walls, a device patented as a result of the design-based research focused on finding new constructive elements in the architecture practice. The use of meta-analyses method and design-based method provide a background for the current research, which follows a mixed-method for designing a novel work environment and finding a suitable framework on which it can be implemented. The framework is a formulation of a more general system, referred to as the mixed matrix (real/virtual), which ensures a logistic for the extrapolated confluence of workspaces. The reality in an office space is augmented by virtual connections that are understood as interchanging written, vocal and video content. The mixed matrix is about interchanging spaces with all their three dimensions. The continuing growth in popularity of remote working, the development of technologies to support it, and statistics on employees' preferences to work remotely or in the office indicate that remote working is unquestionably the solution of the future.

***Key words:*** architecture; technology; communication; remote working; augmented reality.

## 1. INTRODUCTION

### 1.1 Actual state of the problem

This way of working has grown in popularity in direct proportion to the diversification of virtual jobs and tasks, but the real paradigm shift started with one of the most important pandemics in history, COVID-19, which created real challenges in public health, social behaviour and people's psyche. It also left its mark on education and politics, and was the cause of a global economic downturn.

Recent years saw a rise in non-traditional workspaces like home offices and coworking spaces due to flexibility and digitization. COVID-19 furthered this shift, prompting the emergence of virtual coworking spaces. Despite limited academic research, they offer potential for collaborative work and community-building in digital environments, [1]. The digitalization of work has facilitated flexible working since the mid-2000s, blurring spatial and temporal boundaries between work and home. This shift caters to teleworkers and freelancers, providing autonomy in choosing work locations and hours, [2].

#### 1.1.1 Existing concepts

For addressing any kind of work environment involving high flexibility and virtual connections, several terms emerged in the literature: remote working, virtual coworking spaces (VCS), New Ways of Working (NWW),

working from home (WFH), Flexible working spaces (FWS), hybrid work, etc.
Digital technologies have driven organizational changes, leading to distance work like telework, remote work, and working from home (WFH), [3].
The COVID-19 pandemic spurred widespread adoption of New Ways of Working (NWW), granting employees enhanced flexibility and autonomy. NWW, comprising time- and location-independent work, output-focused management, access to organizational knowledge, flexibility in working relations, and open workplaces, promotes employee engagement and intrapreneurial behaviour, [4].
Flexible working spaces (FWSs), including coworking models, have garnered attention across disciplines. They developed as an outcome of challenges faced by remote and rural areas such as poor information and communication infrastructure, [2].
Remote working and virtual coworking spaces (VCS) share similarities in terms of flexibility, granting workers access to global knowledge and widening their audience. However, they both entail drawbacks such as increased effort in online communication, reduced efficiency in collaboration compared to physical spaces, and challenges with non-verbal communication. Both face issues with imbalanced work-home loads.
Virtual coworking spaces (VCSs) combine the best of coworking and remote work, emphasizing social interaction and collaboration. While VCSs lack academic exploration, they're defined by online work sessions with various activities, fostering community and boosting productivity. This sets them apart from remote work, which focuses primarily on task completion. New work models hinge on digitization, skills, economy, and laws. Cultural values and organizational factors shape remote work and virtual coworking, [1].
Facets like autonomy in work timing and location and management of output emphasize results over office presence, while access to organizational knowledge facilitates seamless collaboration. Flexibility in working relations empowers employees to adjust working hours based on personal circumstances, fostering work-life balance. Open workplaces typify NWW environments, encouraging collaboration and communication. The pandemic accelerated NWW's implementation, highlighting its relevance in modern work settings. Research indicates its positive correlation with employee outcomes like work engagement and informal learning. NWW's principles align closely with teleworking concepts, emphasizing the importance of information and communications technology infrastructure - enabling flexibility in contemporary work practices, [4].
While distance work offers benefits such as increased productivity and better work-life balance, it also poses challenges like isolation and blurred boundaries. Access to appropriate technologies is crucial for effective telework. Studies show that WFH can positively impact job-related well-being, but individual differences must be considered. However, there's no consensus on which factors are most significant in shaping telework experiences, nor how they interact. The importance of these factors in enforced WFH remains uncertain, highlighting the need for further research to understand their implications for knowledge workers and how they influence the advantages and disadvantages of WFH, [3].

### 1.1.2 Public perception regarding remote working

Every year since 2020, remote workers almost unanimously want to continue working remotely. In 2020, 98% of respondents said they wanted to continue working remotely (at least for part of the time) [5], and 97% were willing to recommend this way of working to others. In 2021, the number of employees who would like to work remotely at least a few days a week was 97.6% [6], and in 2022 this percentage remained unchanged [7].
Remote work remains highly regarded in 2023, with 98% of respondents desiring its integration into their careers, a slight increase from 2022. Additionally, 98% would recommend remote work to others, signalling growing endorsement. Overall, 91% of respondents report positive remote work experiences, while only 1% express negativity, and 8% remain neutral. Flexibility remains the prime advantage of remote work, with 22% citing time flexibility, 19% preferring location flexibility, and 13% favouring choice of work location. However, one-third of remote workers struggle with feeling homebound due to lack of external reasons to leave, with 23% also grappling with loneliness, depicting the challenges of remote work, [8].
From simply working in an environment different from the space provided by the employer, it is now seen as a flexible work engagement where people can work from places far from the business environment, places from which they have no personal contact with their office colleagues but are able to communicate with them through technology, [9].

## 1.2 Psychological needs, limitations and problems of existing solutions

From a psychological point of view, however, there are a number of disadvantages of working from home. In addition to the blurred barrier between work and family, isolation gives rise to a succession of problems such as depression, increased irritability, weakened immune system, inefficiency, lack of competitive motivation, lack of a real team, etc., [10].

Technological progress has provided several possibilities for remote working and has made collaboration in virtual teams a common way of working, [11]. Today, collaborating in teams with members from different continents is commonplace. One of the main shortcomings of today's remote working solutions is their limited nature. Most of them outline a reduced working environment at the window of a monitor, based on various forms of online connection.

These limitations contribute to problems not only of a mental nature, but also of efficiency and productivity. While working remotely is comfortable and has many benefits, the limited nature of existing solutions means that low productivity and the inability to stay focused for long periods of time are still challenges for a virtual team. The main factor is distraction from various elements in the environment.

Another problem generated by isolation and limited online communication methods is ineffective communication. In remote working, the inability to see the body language of team members has a strong impact on the quality and frequency of communication, affecting performance and the way the team collaborates in the long term.

The limitations of existing solutions can contribute to increased feelings of isolation, which can lead to a range of problems such as depression, increased irritability or even a weakened immune system. Inefficiency, lack of competitive motivation and the absence of a real team are other drawbacks associated with isolation, i.e. working remotely supported by current solutions, [12].

The intersection of family life and work is at a major crossroads today, with remarkable pandemic-driven changes in recent years. New questions are being raised about the future of remote working and the creation of the necessary conditions for employees. This article attempts to provide a solution to both preserve the ability to work from anywhere and to mitigate the undesirable effects of this way of working by implementing mixed real/virtual matrix and Smart Multimedia wall technology. The proposed solution aims at more than just making larger monitors. Through the technology proposed for use, it aims to create a space where people can work as if they were in the same room, in an authentic office atmosphere. Many of the mental, efficiency and productivity problems can be solved by these shared, supervised and organised workspaces.

## 2. MATERIALS AND METHODS

Starting with a literature review, both on office spaces, remote or new types of working and architecture for working spaces, an analysis of working environments' features is conducted. As an outcome, lacking characteristics of collaboration environments are identified – such as three-dimensionality - leading towards the research hypothesis- Table 1.

The goal of the research is to create a specific solution incorporating the missing, yet valuable, features identified in the analyses phase. The solution shell be formulated both in architecture terms, as well as covering the technology used for achieving it. In a following step, the specific solution is integrated in a global concept.

Continuing a previous work about Smart Multimedia Walls and a mixture of virtual and real environments for educational spaces, [13], the applicability is extended for work spaces. For defining a comprehensive application, Building Information Modelling (BIM) software is used, together with 3D rendering software.

The main hypothesis, goal and methods can be seen in Table 1.

Table 1. Research framing

| | |
|---|---|
| **Hypothesis** | Embedding three-dimensionality into a virtual environment supporting collaboration increases quality of working. |
| **Goal** | Create an architectural and technical design solution exploiting the three-dimensionality of space, suitable for extending virtual environments supporting collaboration. Enlarge the specific application to a global concept. |
| **Method** | Using a design-based approach and the Smart Multimedia Wall, create a solution via BIM software and a global concept. |

### 2.1 Materials

The object on which methods are applied are as follows:

- Three-dimensional space – interior of a room inside an office building or inside a residential building;
- Team collaboration virtual environment;
- Smart Multimedia Wall technology.

The addressed environment is composed of the physical space in which one is working and the team collaboration virtual environment used. The physical location is unbounded – in residential building, in company's building or other.

## 2.2 Methodology

The workflow is divided in two major phases: 1 – defining the mixed matrix in a previous study and 2 – transferring the applicability to office means.

### 2.2.1 Phase 1 – SMW and the mixed matrix

Physical space – virtual space blending – the existing mixed matrix for virtual / real space.

Three-dimensional (3D) transfer (Fig and Fig) is defined as recreating an existing 3D space using several displaying surfaces, such as SMWs. This allows the bidimensional surface of a wall to be perceived as a three-dimensional space where another one is working, thus one's own workspace expanding due to the visual perception.

As described in the patent application, [14], the Smart Multimedia Wall is suitable for creating a transparent glass surface where opacity degree can be adjusted, while displaying images, static or video. This allows displaying content on large areas enclosing the interior space.

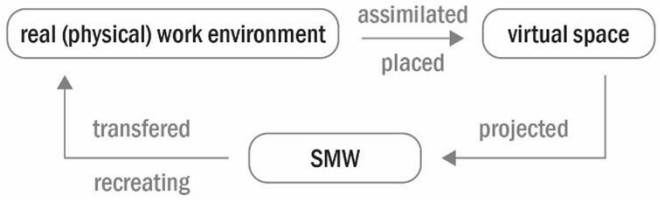


Fig. 1. Real / virtual space loop

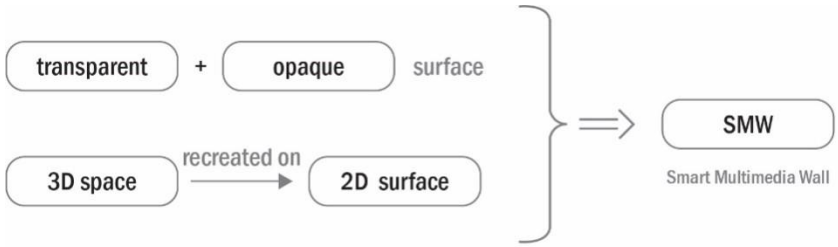


Fig. 2. SMW for 3D transfer

Functionally, the SMW comprises a composite structure characterized by its capacity to modulate transparency and facilitate multimedia playback on transparent or opaque substrates. This capability enables the concurrent display of multimedia content on both sides of the wall surface, thus fostering immersive experiences and adaptive privacy settings within the surrounding environment, as in **Error! Reference source not found.**.

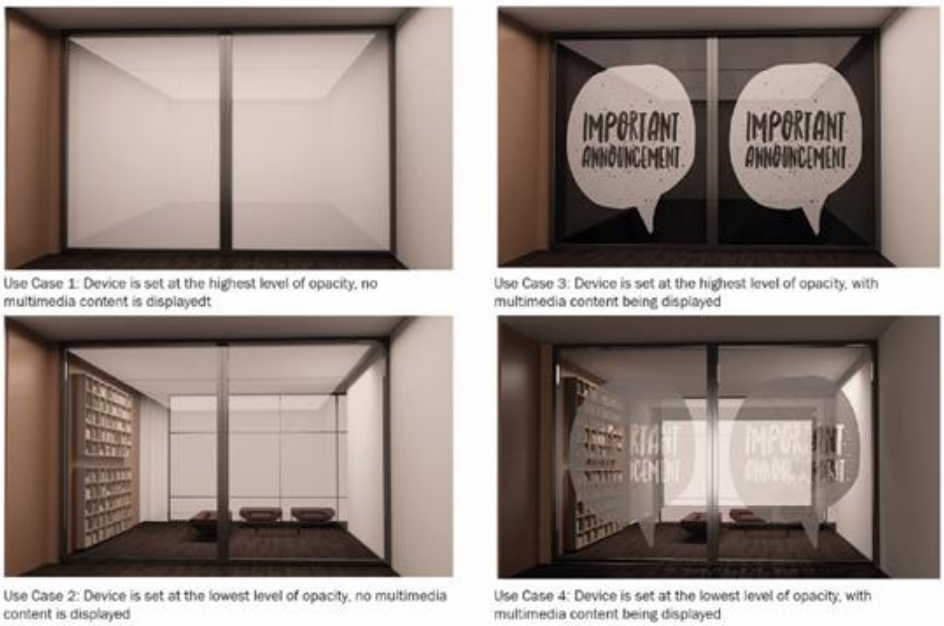


Fig. 3. Use cases for Smart Multimedia Wall (SMW), [14]

The Smart Multimedia Wall (SMW) is constructed through a multi-layered assembly comprising several key components, depicted in Fig. 1. These include outer protective layers fabricated from glass (1), configurable transparent liquid crystal panels capable of displaying colour images utilizing the RGB spectrum (2), internal glass sheets serving as structural support and reinforcement (3), and a configurable monochrome liquid crystal panel (2) utilized for regulating ambient brightness by modulating transparency levels.
Additionally, the device is enhanced by a sophisticated data processing and control system (7), which facilitates interaction with external devices for multimedia content retrieval and management of the two colour displays (2) and monochrome display (4). The data processing and control system incorporates essential features such as a power supply port (5) and an array of data communication interfaces (7) encompassing Ethernet, Wi-Fi, Bluetooth, HDMI, Display Port, and VGA connectivity, [14].

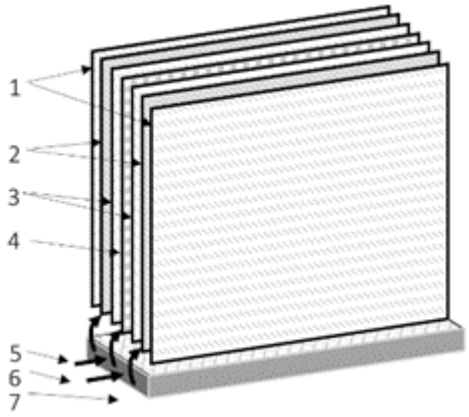


Fig. 1. SMW layers, [14]

According to the previous study on educational spaces, [13], the mixed matrix framework embodies the duality of virtual and physical environments by bringing physical spaces together. The mixed matrix is about interchanging spaces with all their three dimensions, besides the written, vocal and video content.
Within this framework, the virtual space serves as an abstract arena where connections between disparate physical spaces are established. In contrast, the physical space represents the tangible environment in which individuals are situated, characterized by the integration of Smart Multimedia Walls (SMWs). These SMWs function as dynamic elements within the matrix, displaying projections of remote workspaces, thereby blurring the distinction between physical and virtual dimensions.
The resulting environment is inherently hybrid in nature. By seamlessly merging virtual representations with physical surroundings, the mixed matrix fosters a fluid and immersive experience.

### 2.2.2 Phase 2 – transfer to team collaboration virtual environment

The next phase is focused on transferring the applicability of the mixed matrix towards office spaces. There is an overlap between the mixed matrix and the already existing team collaboration virtual environments used in companies – the virtual connection between people. The distinctive augmentation introduced by the mixed matrix framework lies in its incorporation of three-dimensional (3D) spatial exchange capabilities.


Fig. 2. Common workspace compose of workspaces at home (WH)

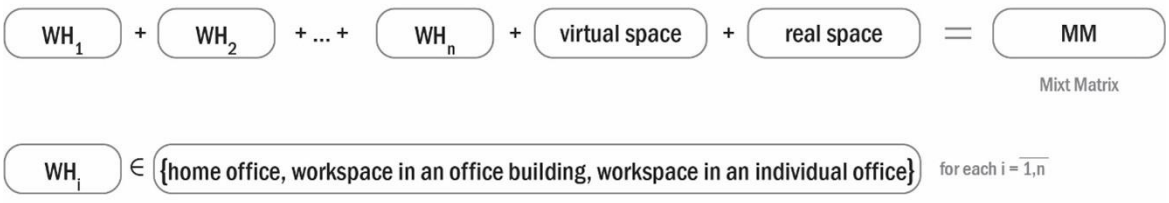


Fig. 3. Organisation of the mixed virtual-real matrix (MM)

As previously seen, large corporations in particular are currently facing two major problems in terms of how the shared workspace serves its purpose:

•On the one hand there is the obvious opportunity to continue working from home online, given that a large proportion of employees prefer this way of working. However, the need to make online working more efficient is also exposed, as a loss of productivity can be noticed in a rather short period of time (due to loss of interest or focus of those working online);

•On the other hand, there is a need to facilitate teamwork between those who work online and those who prefer to work on site, in the traditional office space provided by the employer. This becomes possible by integrating everyone in a common space, a hybrid real-virtual space.

The proposed solution succeeds in improving and streamlining the process of using the common workspace, which can be configured in different operating scenarios, consisting of workspaces, referred further on as workspaces at home (WH) and shown in Fig. 2 and Fig. 3.

## 3. RESULTS AND DISCUSSION

### 3.1 Results

Central to this solution is the Smart Multimedia Wall (SMW). Functioning beyond mere spatial enclosure, the SMW expands the boundaries of physical space by enabling multimedia content display on both sides of its surface while affording control over privacy levels through opacity adjustments.

Utilizing Smart Multimedia Wall (SMW) technology in conjunction with a mixed matrix strategy, the conventional office space has the potential for enlargement by integrating SML technology into two of its walls. This adaptation addresses the confines of physical space and sets a trajectory towards future workplace evolution. The configuration of the workspace can be adjusted depending on the nature of tasks being performed. Within the framework of SMW, several scenarios are proposed, each offering three multifunctional possibilities:

• Expansion to accommodate additional personnel: This could involve either partially or fully adding office rooms to accommodate employees from disparate locations.

• Spatial extension: This scenario encompasses the projection of images or the transfer of the entire workspace to a virtual setting.

• Visual extension: By rendering the SML technology fully transparent, the workspace becomes visually connected to surrounding circulation areas or adjacent spaces.

### 3.2 Typologies

This simple and yet flexible piece leads to several typologies, according to the way the workspace is obtained: full room, by division or by addition.

1) full Room - An existing full room can be converted into a Workspace at Home (WH) by transforming 1, 2, 3 or even 4 walls into SMW. This procedure is suitable for residential, both apartments and houses, as well as for office buildings (Fig. 4).

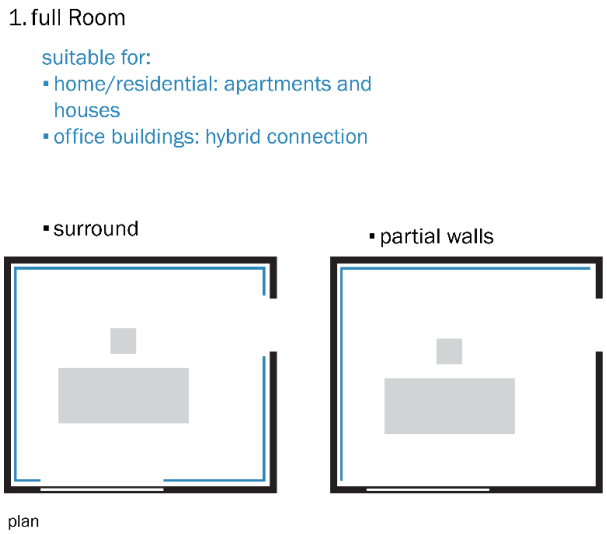


Fig. 4. Typologies for Workspace at Home (WH) – full room

2) by Division - Another way of converting an existing space is by division. A WH is created by partitioning a room with fixed or mobile SML, being at use for residential spaces, to separate a living room from a WH or to further divide an existing workspace. In terms of office buildings, an open space can become several smaller WHs, leading to a hybrid work environment Figure 8.

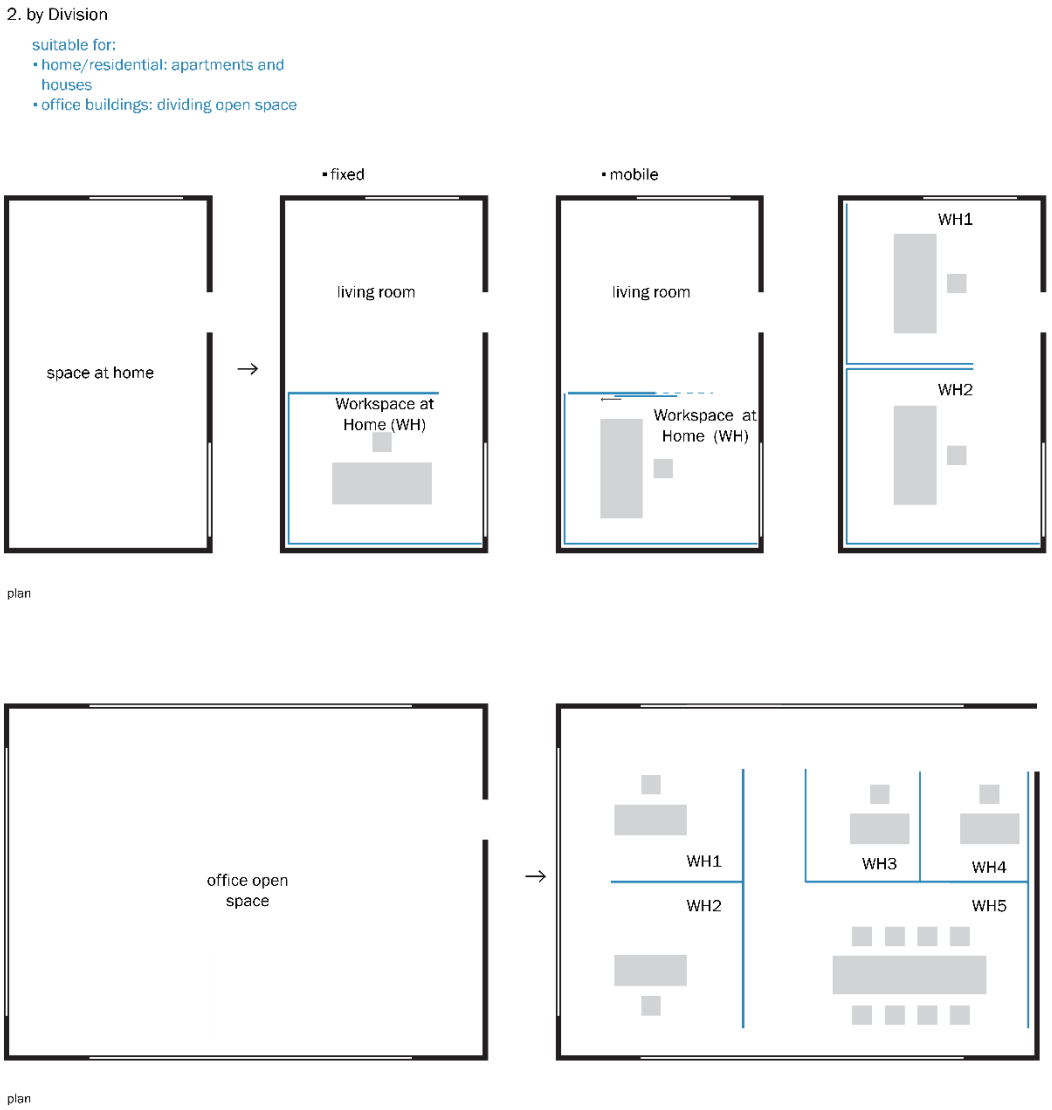


Fig. 8. Typologies for Workspace at Home (WH) – by division

3) by Addition - A WH can be added to a living space, completely of partially detached to the building, such as an extension of a house or an intervention on the rooftop of an apartment building Fig. 5.

### 3.3 Housing solutions - connecting homes to the mixed real-virtual matrix

An effective way to prevent the above-mentioned needs and problems even when working remotely is to create a series of dwellings in which the work area is separated from the living area and is permanently connected to a virtual mixed matrix, regardless of the scenario (sea, mountains -**Error! Reference source not found.**, Danube Delta - **Error! Reference source not found.**, Fig. 6, Fig. 7, Fig. 9, urban setting - **Error! Reference source not found.**, Fig. 8, etc.). This series can give people the chance to retreat anywhere (in nature, in an urban environment different from their workplace or in any other preferred space) and work from there.

The module connected to the mixed real-virtual matrix may (Fig. 7) or may not (Fig. 6) be separated from the living area of the house. For psychological reasons, in order not to mix home and office life, the example we will suggest is where the work space is detached from the home. Such a gesture accentuates the clear barrier between private and professional life, both in the volume of the solution and in the psyche of the users. Although the working mode will still be remote, the fact that people have to leave the home to get to the module (WH) connected to the matrix is yet another element that induces the feeling of going to work.

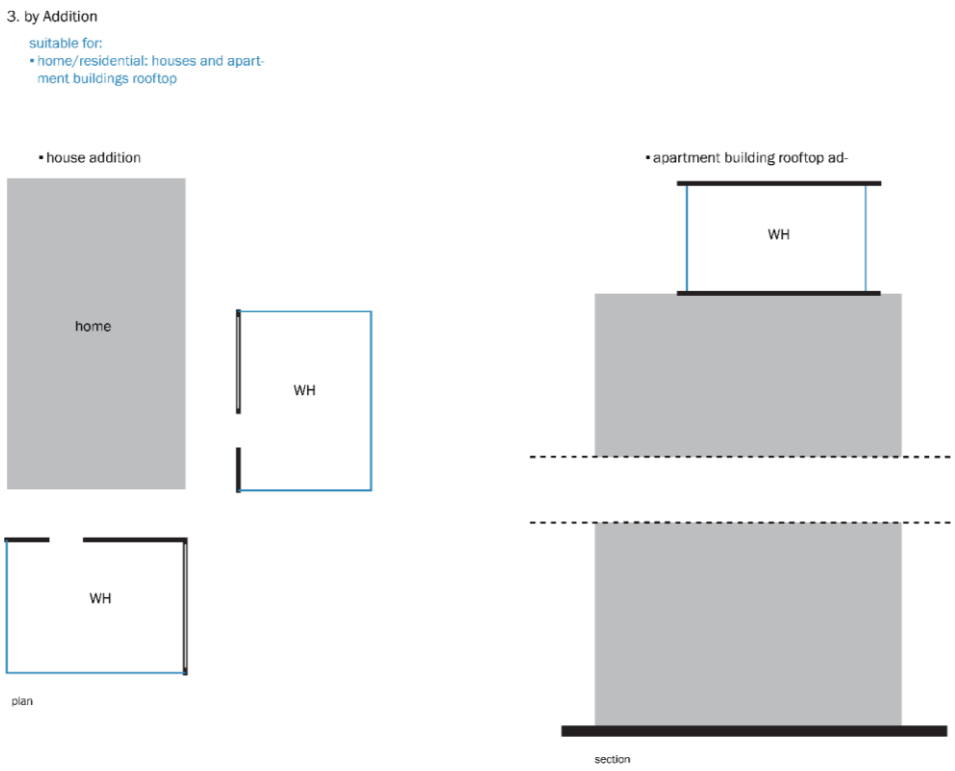


Fig. 5. Typologies for Workspace at Home (WH) – by addition

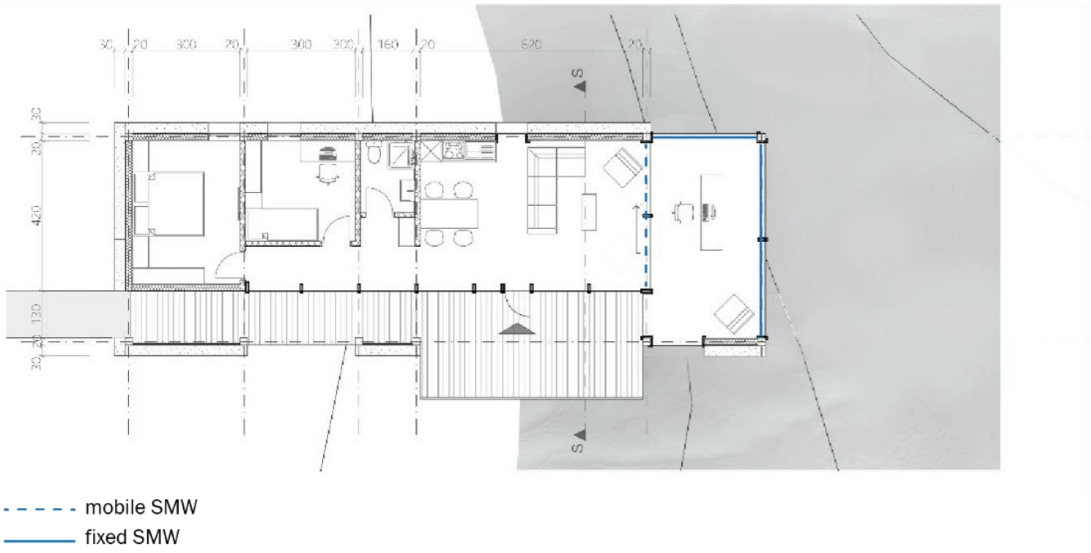


Fig. 6. Housing variant with the module (WH) attached to the living space of the house

The way the home is organised is relatively simple. Both the main access and the route to it are protected by the eaves of the house. The welcoming image offered by it involves an open space comprising both the living area and the kitchen together with the dining area. To the left is grouped the night area, together with the sanitary group. Compared to current solutions, the innovative element is the addition to the existing living space of a module permanently connected to the matrix. The module may or may not be detached from the home, depending on the user's preference. The practical aspects involve the use of Smart Multimedia partition walls/windows, [14], which allow both the simultaneous display of two different multimedia contents on both surfaces of the active area, and the controlled change of opacity to intimate or visually separate the space.
The module attached to the housing presents three such walls and video cameras in the direction of each. This technology will enable the creation of an authentic office atmosphere where employees can enjoy each other's presence and interact with each other at any time. The possibility of fully rendering the workspace, merging it with other workspaces and generating a virtual shared space would eliminate the shortcomings associated with working bounded by a monitor window or other online forms that are insufficient.

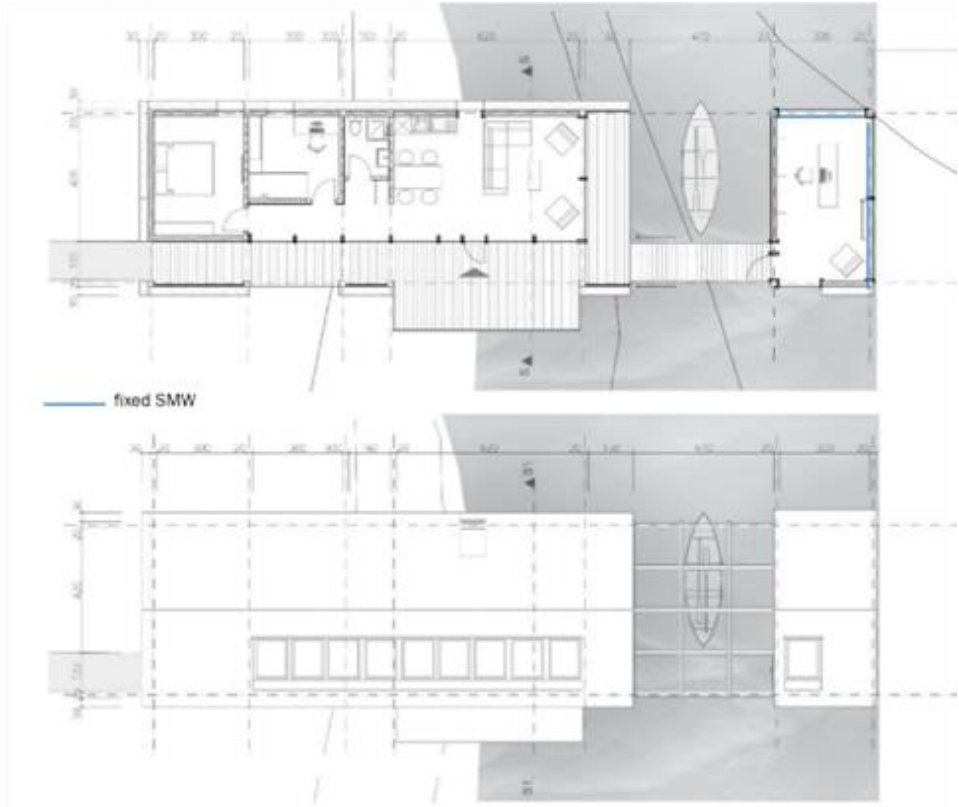


Fig. 7. Housing variant with the module (WH) attached (while separated) to the living space of the house, floorplan (up) and roof plan (down)

Integration into the mixed real-virtual matrix is made possible by the presence of Smart Multimedia partition walls/windows in the body of work, which can control the degree of transparency and display multimedia content interactively. Their use would be a significant addition in recreating an authentic office atmosphere where employees can enjoy each other's presence and interact with each other at any time. This would remove the psychological consequences of isolation, as people are able to bring part of the corporate working environment into the home scenario on a daily basis. They would no longer have to commute to the office every day, nor would they be affected by it.

The detached solution presented above was previously developed for the Competition "Casa mica - Casa cuib 2022" (Small house – Nest house) by the authors, [15]. The purpose was designing a small house with complete freedom in terms of location. Acknowledging the usual housing solutions, it can be observed how the workspace module, referred previously as WH, with Smart Multimedia Walls (SMW) is amplifying the existing space, thus transforming it into a mixt virtual-real space.

Fig. 12. Workspace at Home (WH) as an addition to a house in Danube Delta

Fig. 13. Workspace at Home (WH) as an addition to a house in the mountains

### 3.4 Global concept – confluence of spaces – joining people

It was shown how using SML a four-wall enclosed space can expand into much more, one being able to see and perceive another one's workspace. Further on, it is developed the concept of mixed matrix – virtual/real for

workspaces. The matrix is technically understood as a bidimensional array where its elements consist of Workspaces at Home (WHs) and each WH is associated with the person using it.

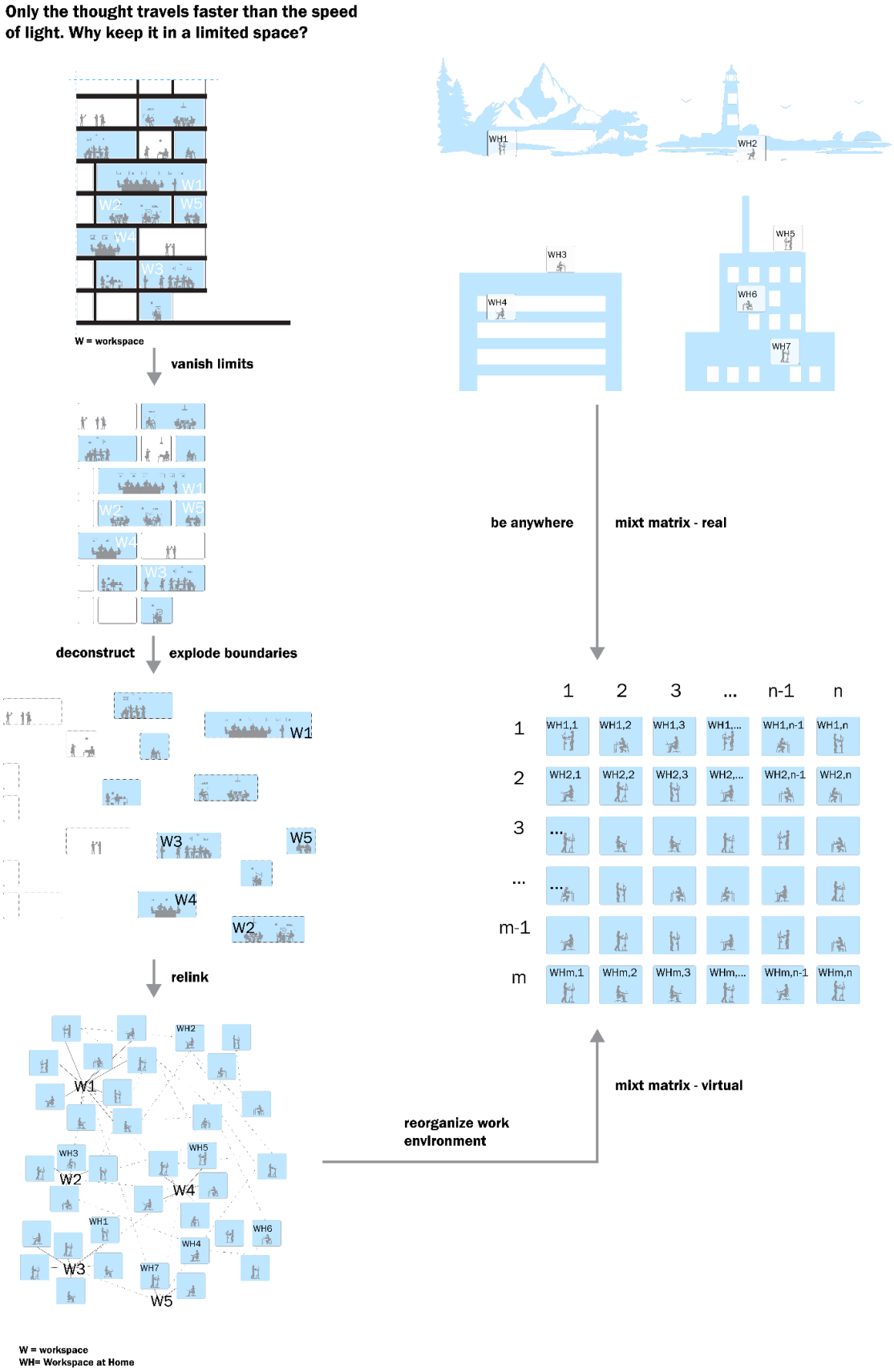


Fig. 14. Mixed matrix for workspaces - scheme of global concept

All the rooms designed in an office building, such as individual offices, open space office, meeting rooms, can be constituted in every WH by bringing spaces together. The reality in an office space is augmented by virtual

connections that are understood as interchanging written, vocal or video content. The mixed matrix is about interchanging spaces with all their three dimensions. A meeting room is a collection of multiple WHs and each employee can perceive, as a continuation of the personal space, the spaces in which the other colleagues are.
The mixed matrix is a framework with two kinds of spaces: virtual and physical. The virtual space is where the abstract linking is made between workspaces. The physical space is where one finds himself, in the WH with Smart Multimedia Walls which shows a projection of the space where another one is working, both being an element in the matrix. The overall created environment is a hybrid one, vanishing the limits of virtual and real - **Error! Reference source not found.**, expanding the concept of virtual coworking spaces.
Practically, this mathematical approach to orchestrating shared workspaces involves the creation of a matrix comprising two to n elements. These elements correspond to designated workspaces, specifically the home work area and the office space within corporations. These distinct spaces are interconnected, seamlessly extending the boundaries of each other's physical environment through the patented Smart Multimedia Wall technology.
The necessity of this kind of scheme follows the need of having a virtual structure on which all types of connections can be made, thus enhancing communication between colleagues. The conventional office building, dictated by an architecture of physical spaces, is seen differently as a collection of Workspaces (W) interconnected, this time, by the virtual matrix. The circulation spaces that bound all the rooms in an office building are equivalent to the virtual connections in the matrix, joining all the company employees in a united virtual space that is perceived similar to physical space. All the physical limits in the office building are vanished and the Workspaces (W) are taken out, deconstructed and understood as a group of people, each fellow coming with his own Workspace at Home (WH). The next step is relinking the WHs in the mixed matrix. In the digital grid of the MM all the WHs are connected and perfectly framed, regardless of the scenario in which they have been installed, resulting complete freedom of placement in any of the scenarios (mountain, sea, Danube Delta, urban setting, etc - **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**, Fig. 8).

Fig. 15. WH in urban setting, on apartment building rooftop

Fig. 8. WH in urban setting, on apartment building rooftop

All the WHs are situated, on one hand, in the virtual space of the mixed matrix (e.g. **Error! Reference source not found.**), and on the other hand, anywhere in the physical word (e.g. **Error! Reference source not found.**), including offices buildings, homes (houses and apartments) or natural surroundings. This framework encourages mixed teams, Workspaces (W) containing people at the office, others at home or anywhere else. The solution is also suitable for companies with several locations across the word, allowing employees to team in the virtual space. The WH has two or three walls with SMW and video cameras from each SMW direction. Having this technology, one can recreate the authentic office vibe where the employees can enjoy each other's presence and can socialize, the visual connections being rendered in Fig. 9 and Fig. 10.
Working in teams can become similar to working in a physical office. The ability to render the entire workspace, to merge it with other workspaces and to generate a virtual common space eliminates the shortcomings associated with working bounded by a monitor window or other online forms that are insufficient.
The mixed real-virtual matrix can make teamwork even more efficient, by making it possible to instantly swap spaces in the matrix according to the temporary needs of the individual or team. In real life, such changes are harder to make, requiring time and effort that can affect employee productivity. All the spaces in an office building can be transposed into the matrix and arranged at any time according to the needs or preferences of employees. It allows people from all over the world to be present at work, managing to bring part of the corporate working environment into the home scenario on a daily basis. This way of working allows people to choose their office colleagues at any time according to the needs of teamwork, gives them the freedom to retreat anywhere and saves them the daily commute. Within each of the two or three walls, employees have the choice

to oscillate between having direct contact with the outside world, playing media content or interacting with other colleagues. They can create their own working atmosphere without being isolated. They can also take up a new job while retaining some familiar surroundings or a favourite place. The workflow of the MM is presented in, Fig. 10.

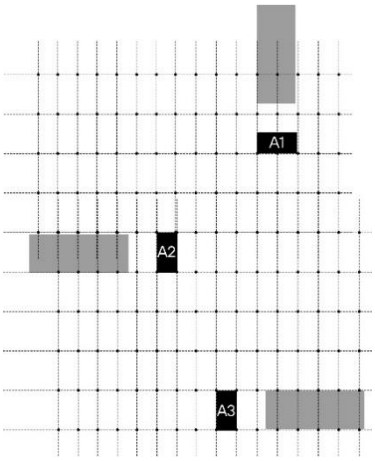


Fig. 17. Virtual space of the mixed matrix with Workspaces at Home - A1, A2, A3 – following the concept of virtual coworking spaces

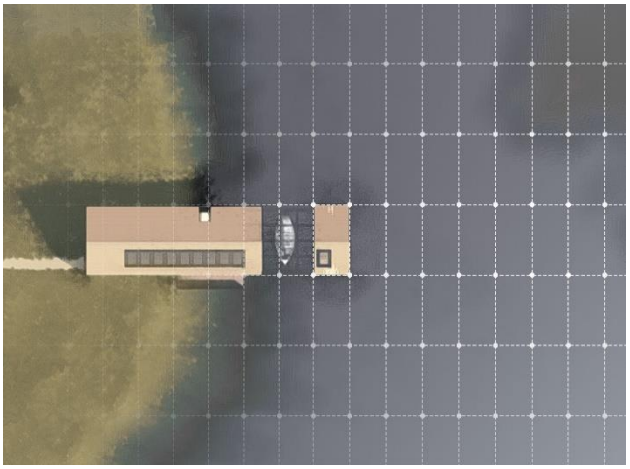

Fig. 18. Real space of the mixed matrix with Workspaces at Home

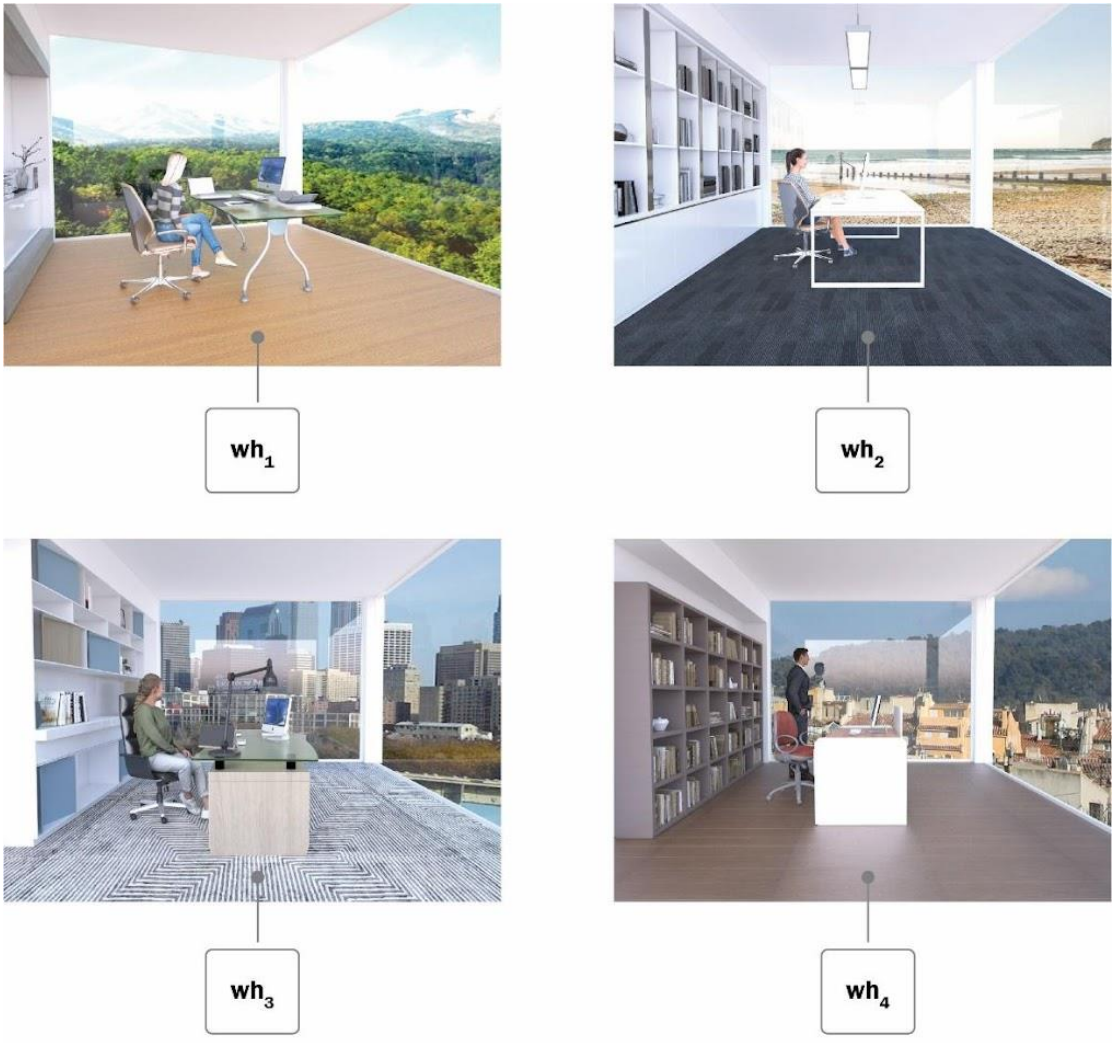


Fig. 9. Workspace at Home (WH) implies working from anywhere: mountains for WH1, seaside for WH2, urban environment for WH3, office building in urban context for WH4


Fig. 10. Mixed Matrix (MM) organisation and workflow – The employees have the possibility to choose their colleagues and work in teams in an authentic office atmosphere, with the possibility of being anywhere.

### 3.5. Discussion

#### 3.5.1. Problems of remote working solved by implementing the mixed real-virtual matrix

The implementation of the mixed real-virtual matrix is not only an enabling measure for remote working, but also the solution to the many problems that remote working creates. It succeeds in satisfying both employees who want to continue working from a preferred setting and companies who want to bring them back to shared, supervised and organised workplaces.

A first disadvantage of working from home was the diminishing barrier between work and family. This has been solved by separating the living area functionally and in volume from the working area. The module, which is permanently connected to the matrix, thus offers the possibility of working remotely without the danger of mixing the office scenario with private life.
Isolation breeds a range of problems such as feelings of loneliness, depression, increased irritability and a weakened immune system. Together, the technology implemented in the work module and its integration into the mixed real-virtual matrix make it possible to achieve an authentic office atmosphere, where employees can enjoy each other's presence and interact with each other at any time. The ability to fully replicate the workspace and merge it with other workspaces enables the generation of a virtual shared space and eliminates the problems associated with working limited by a monitor window or other online forms. With the matrix, people will no longer have to commute to the office every day, but will be able to be a part of it from anywhere in a working space that can be associated to a virtual coworking space.
Inefficiency, [9], lack of competitive motivation and the absence of a real team were other drawbacks associated with isolation and remote working. As the level of immersivity of the Smart Multimedia windows is high, the atmosphere created by the matrix is almost identical to that of being physically present in the office. People can work from home without feeling or being psychologically affected by it. They can observe each other and interact as if they were in the same real space, thus the physical office space is re-generated in every WH. The only difference is that they will be able to work from whichever scenario the home is set up in. The mixed real-virtual matrix can make teamwork even more efficient, by being able to instantly swap spaces in the matrix according to the temporary needs of the individual or team.
Ineffective communication was another problem caused by isolation and limited online communication methods. In remote working, the inability to see the body language of team members drastically affected the quality and frequency of communication, altering team collaboration and performance over time, [16]. The possibility of fully translating the real space into a matrix, of creating a virtual shared space where employees can see each other just as they do in the office solves this problem entirely.
From a task management point of view, planning and reviewing work progress is much harder to do in the home office, as monitoring work is done through face-to-face meetings and discussions. The possibilities for interaction of the matrix, mentioned above, also remove this problem.

### 3.5.2 Shortcomings

The shortcoming of the mixed matrix for workspaces revolves around several factors: senses replication, economic and technological demands.
Being a solution that replicates the reality using virtual connection and displays, it is debatable how well the mixed matrix can fully mimic the authentic office atmosphere. While reconstructing tridimensionality of space at scale, the employees cannot have physical contact. Other senses like smell or touch are not replicated.
By technological means, the assembly of a WH involves the virtual network and the specific hardware consisting in the SMWs, cameras and microphone. These resources might not be affordable for small companies or individuals, although the required technology is becoming increasingly affordable. Besides equipment, installing such a system requires specialised knowledge, setting it up being less convenient than the virtual environments supported by personal computers or laptops.
Depending on online connectivity, the mixed matrix framework is highly relying on good internet connection. Interruptions or small speed of sending and transmitting data might suspend its functionality. For reconstructing a 3D space at scale, cameras transmit high resolution videos over the internet, thus challenging connectivity.
While offering flexibility in terms of choosing the work location, the mobility of the WH is limited after set up because of the fixed position of SMWs. Even if they can be repositioned, moved or transported, it involves an increased effort compared to the mobility of a laptop. When put in balance with other technologies such as video projectors or smart boards, shortcomings appear similar: heavier equipment, large smooth surface needed for projection.

## 4. CONCLUSIONS

Despite the fact that the pandemic was not the main cause of the emergence of remote working, it was a revelation of this system. People had the opportunity to experience the advantages and disadvantages of remote working on a large scale.
The continuing growth in popularity of remote working, the development of technologies to support it, and statistics on employees' preferences to work remotely or in the office indicate that remote working is unquestionably the solution of the future.

Post-pandemic, workplaces are expected to continue offering remote work options to meet demands for flexibility. Public and private sectors globally are transitioning towards this, aiming for sustained performance, well-being support, and potentially reduced office space. However, concerns over mental health and well-being outcomes associated with remote work are emerging, [3].

Managers anticipate shifts in workspace dynamics post-pandemic. While virtual work will increase, physical coworking spaces seem vital for meetings and collaboration. Some envision reduced shared spaces but maintain physical gatherings for certain activities. Flexibility enables work-life balance, with options for remote work and diverse locations. Strategies include expanding businesses to less affected areas and adjusting fees. Both virtual and physical coworking are seen as sustainable options among changing work practices and reduced travel, [1].

Although it has a number of drawbacks, mainly of a psychological nature, the mixed real-virtual matrix aims to address them and succeeds in satisfying both employees who prefer to work from anywhere and companies that want to bring them back to shared, supervised and organised workspaces following virtual coworking spaces concept.

The principal outcome of the study pertains to the development of a mixed matrix framework for workspaces characterized by two distinct spatial dimensions: virtual and physical. The virtual space serves as a conduit for abstract connections between different workspaces, while the physical space represents the tangible environment wherein individuals are situated, notably within the context of Smart Multimedia Walls within the WH, projecting the activities of other users. These elements collectively form an integrated hybrid environment, effectively blurring the boundaries between virtual and physical realms.

The proposed solution adeptly targets the enhancement and optimization of the workspace utilization, accommodating various working scenarios through flexible configurations. Whether situated within residential or temporary living environments, the home-based workspaces (workspace at home - WH) are seamlessly integrated into a mixed virtual-real matrix, facilitating a fluid transition between different modes of engagement. This innovative solution transcends the limitations of conventional online connectivity, which typically relies on monitor-based interfaces. Instead, it proposes the implementation of Smart Multimedia Wall partitions to delineate and facilitate communication among the interconnected spaces within the mixed matrix.

A paramount challenge in remote working revolves around meeting psychological needs, particularly those concerning social inclusion, fostering connections among peers, and cultivating a sense of community within a designated space. The conventional workplace setting offers employees familiar physical environment, which fosters a sense of belonging and spatial orientation. Conversely, remote working often relies on transmitting two-dimensional images on screens, significantly diminishing the perception of a shared three-dimensional working environment.

Ineffective communication further exacerbates the challenges of remote working, compounded by feelings of isolation and limited online communication modalities. The absence of non-verbal cues, such as body language, profoundly impacts the quality and frequency of communication and consequently influences working outcomes. To address these challenges, the notion of translating physical space into a virtual matrix offers a promising solution. By creating a virtual shared space where employees can interact visually in real-time, akin to a traditional office space setting, this approach facilitates more nuanced communication and a sense of spatial presence. Displaying employees' images in true scale on a large multimedia wall simulates the work office experience, enabling employees to perceive facial expressions, gestures, and other cues with greater fidelity, thus fostering a more immersive working environment.

While solving several issues regarded to psychological and social needs of employees, the mixed matrix for workspaces requires testing for understanding and unfolding its implications. For the next steps, a reduces model shell be constructed for assessing user comfort and performance. Such an innovative solution demands further studies and testing if intended to become a product. At this phase, the presented study consists of the theoretical basis for a further prototype.

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