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# Preliminary Proposal for an Alternative Wall Lining Panel Based on Molded Recycled Cellulose and Designed for Home Wiring Refurbishment of Building Interior Partitions

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**Abstract:** Old dwellings usually have shortfalls in insulation, acoustic and thermal, and in security of electrical services in the interior partition walls. A common building solution is to add a wall lining with a laminate base gypsum board that improves both acoustic and thermal insulation and facilitates a new invisible cable layout without demolition. Conventional solutions have had limited success because of time consumption, environmental impact and cost. This research aimed to create an integrated building system to carry out these interior building refurbishment works quickly, cleanly and with low inconvenience and environmental impact. The research specifically focused on incorporating new molded materials that have a low environmental impact and improving the handling and future modification of the wall lining system. In response to the above goals, the product development methodology was applied to the design of an internal panel to be inserted between the existing partition wall and the closure wallboard, which is usually laminated base gypsum board (LGB). The proposed internalpanel is molded with recycled cellulose pulp (*Biprocel*) and has adequate relief designed to improve cable layout tasks and better join the laminate base gypsum board to the existing wall face. The development resulted from collaboration between the public administration, university researchers and undergraduate students in the co-design process. This research contributes to improving the applications of recycled cellulose fibers in molded panels for the building industry, particularly in refurbishment activities.

**Keywords:** molded panels; cellulose pulp; wiring layout system; wall lining; interior partitions; dwelling refurbishment



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## 1. Introduction

In Western countries, the housing sector is facing the widespread problem of refurbishing urban-dwelling stock to update electrical services and improve insulation performance in line with the needs and aspirations of the population: increased comfort, reduced energy consumption and the introduction of home digitalization [1,2]. This improvement in the built environment should occur in three stages: city, buildings and private dwellings, with a clear diversity in the available resources and governance systems [3,4] in different countries.

Turnover in property owners and users occurs daily because of continuous social and individual changes. Each change in owner or user of a dwelling is accompanied by additional private investment to adapt the interior space to the new occupants. Interior partition walls are one of the building elements that are usually altered throughout its life cycle.

Building techniques for removing and replacing interior partition walls that are in use in the construction market are not very efficient in terms of time and waste at the building site, leading to high economic and environmental costs. This is probably because these building techniques were developed in a historical period in which salaries were low, work processes were traditional, and site work could be disturbing and unhealthy for the neighborhood because of noise, dust and waste. It is a challenge to update building techniques for interior partition walls focusing on current social and climate changes. Any reengineering of this interior building element must be aligned with the current vectors of evolution:

(1) Periodic changes in the user of the housing stock (rent and purchase);
(2) Home-scale renewal, aligned with buildings and city refurbishment policies:
(3) The growing need for more wired services (energy, security, sensors, lighting, communication, etc.) at home, which does not seem to be slowing;
(4) New "green" refurbishment technologies to make the circular economy a reality [5].

## 2. Literature

First, a review of the existing literature is presented, which allows us to group the research into three sections: scientific-technical, industrial and commercial.

### *2.1. Current Situation of Electrical and Wire Services in Housing*

The safety of the oldest electrical installations in homes is a concern in European Union countries, given the current renovation rate of homes and, more specifically, of their electrical installations. In addition, using domestic electricity continues to grow and evolve. Its intensity and complexity are increasing in terms of the quality and safety of electricity used in homes alongside other aspects, such as home automation, telecommunications, self-generation of power, etc. [6].

The results of a study carried out in Spain [7] show in detail some qualitative and quantitative aspects of this situation:

(1) 23.87% of living room switches have been modified from the original layout;
(2) 25.4% of bedroom switches have been modified from the original layout;
(3) 23.6% of kitchen switches have been modified from the original layout;
(4) 35.13% of living room sockets have been modified from the original layout;
(5) 40.93% of socket outlets are hidden by furniture;
(6) 35.20% of plug positions have been modified from the original layout;
(7) 38.07% of bedroom sockets are hidden by furniture;
(8) 29.6% of kitchen plugs have been modified from the original layout;
(9) 77.67% of plugs in living rooms connect adaptors, spools or extension cables;
(10) 64.20% of plugs in bedrooms have spools or extensions connected.

In the case of telephony, data and TV networks, the following results were found:

(1) 31.7% of telephone connections are modified from the original layout;
(2) 16.7% of telephony connections in living rooms have been modified from the original layout;
(3) 38.5% of telephone connections in bedrooms have been modified from the original layout;
(4) 12.7% of telephone connections in bedrooms have been hidden by furniture;
(5) 33.3% of data and TV connections in living rooms have been modified from the original layout;
(6) 18.1% of data and TV connections in living rooms have been hidden by furniture;
(7) 40.7% of data connections and TV in bedrooms have been modified from the original layout;
(8) 13.8% of data and TV connections in bedrooms are hidden by furniture.

This scientific-technical study reveals the need to develop specific technologies to facilitate changes and/or the relocation of surface elements of the wired services that are supported on interior wall partitions, not only for comfort but also for security (Figure 1).

**Figure 1.** Example of the current situation of electrical and wire services in dwellings (source: authors).

### 2.2. Commercial State of the Art

The summary shown in Table 1 indicates that only a few technical systems are available on the building market for the layout of wired installations, and no recent contributions were found. This situation contrasts with the broad scope of current regulations [8], which allow a greater number of solutions than those that are currently implemented. However, the characteristics of wiring are continuously evolving and diversifying, as shown in Table 2.

**Table 1.** Summary of wiring layout technologies in residential buildings (source: authors).

| Strategies | Weaknesses | Strenuous | Threats | Opportunities |
|---|---|---|---|---|
| Wall chasing | Affects the basic performance of the wall (isolation, stability) | Produces noise, dust and waste, affects workers' safety, and requires a great deal of time to do and undo activities | Very cheap | No need to forecast future needs |
| Surface technical channels | No flatness | Alters the visible architectural appearance | Easy handling | Available everywhere and with various kinds of accessories |
| Wall lining | Loss of habitable volume | More expensive | Not visible | Improves other aspects of wall performance: acoustic, fire, thermal, etc. |

**Table 2.** Summary of the standardized technical characteristics of the cabling that is considered.

| Cables | Comments |
|---|---|
| RZ1-K 0.6/1 kV, nominal sections of 1.5 and 2.5 mm$^2$ | Reference standards:<br>• Dimensions and material, UNE 21123-4;<br>• Identification of drivers, UNE 21089-1 (HD 308);<br>• Fire behavior test, UNE 21123-4 |
| Effective voltage (U) of 1 kV for use in fixed installations | |
| Rated voltage 0.6/kV test voltage 3.5 kV C.A (5 min) | |
| Cross-linked polyethylene (XLPE) insulation, type DIX3 according to HD 603-1. Cover made of polyolefin PO | According to Annex 1, UNE 21123-4 |
| Minimum radius of curvature<br>4Ø if Ø < 25 mm and 5Ø if 5 mm $\leq$ Ø $\leq$ 50 mm | The nominal section of 1.5 mm$^2$ is suitable for the supply of 10 A consumer lighting;<br>The nominal section of 2.5 mm$^2$ is suitable for feeding bases between 16 and 20 A;<br>The outer Ø of these nominal sections is 5.7 mm and 6.2 mm, which means that the most restrictive radius of curvature is 24.8 mm. |
| Electrolytically twisted flexible copper conductor class 5 according to UNE 21022/IEC 228 | It is substantially cheaper than using a "hose". |
| Telephone conductors: cables of 1 pair EV 0.51 mm with an outer diameter of 3.7 mm are taken as a reference. | It is comparable to most drivers used in pre-existing telephone installations in the study area. |
| Data conductors of 6.1 mm outer diameter FTP Class D, Cat5e cables are taken as reference. | It is comparable to most of the conductors used in pre-existing telephone installations in the study area. |
| Coaxial 75 Ω, 6.6 mm outer diameter cables are taken as reference for television drivers. | It is comparable to most drivers used in pre-existing television installations in the study area. |

The usual cabling technique for wire layout on wall lining is the insertion of cable conductors into a tube linked to the framework of the wall lining. This solution is suitable-and meets current standards but can be improved to reduce the environmental impact and avoid thermal and acoustic bridges (Figure 2).

**Figure 2.** General view of today's wall lining system at a work site.

The wall lining system now seems to be the right solution to foster interior dwelling renovation and support new wiring layouts. The current mainstream solution for wall lining is laminated base gypsum board (LGB) [9]. Some national and international construction codes consider this a viable alternative due to its adequate cost–benefit ratio [10–12].

The use of wall liners avoids demolition work of ancient interior partitions and, therefore, reduces time, debris and accidents. Subsequently, it provides a useful air chamber for the layout of new facilities or the insertion of materials with insulating properties. Finally, it is clad with a light laminate base gypsum board that reproduces conventional interior home finishes.

It seems reasonable to explore the possibilities of evolution of the wall lining itself to adapt to the growing need for renovation and updating of interior vertical walls. Some recent commercial systems, such as HISPALAM [13] or MURALIT [14], introduce the possibility of directly gluing the laminated gypsum board to the existing masonry wall. This evolution points to creating continuous support for LGB wall lining as a way to reduce thickness.

The commercial references that were consulted show that the wiring technology is highly developed and standardized, but the technologies for its layout in buildings still must evolve further to adapt to the processes of updating, replacement and reconfiguration. The lack of integration with other building elements, such as thermal and acoustic insulation, is also evident. Everything points to the opportunity to develop systems that integrate both challenges.

### 2.3. Industrial State of the Art

The state of the art of innovative systems for the integration of wire layout and lining walls was consulted on several patent databases:

(1) Patents for invention and utility models of the Spanish Patent and Trademark Office (SPTO), INVENES;
(2) European Patent Office, ESPACENET;
(3) GOOGLE SCHOLAR, patent portal.

Numerous keywords, their derivatives (plural, words with the same root, etc.) and combinations linked by logical operators were used in the above patent databases. The following English terms and keywords were found: plasterboard, drywall, cable, clad, installation, lining, partition and panel. In addition, the 8$^{th}$ edition of the *International Patent Classification (CIP)* was used with the following codes:

(1) E04B2 walls, for example, partitions for buildings, the structure of the walls regarding insulation, specific mounts for walls;
(2) E04C2 construction elements of relatively little thickness to construct parts of buildings.

When this search was completed, many patents that describe types of walling systems were referenced, including wiring layouts, which are most closely linked to the aim of this research.

Some relevant patents are shown in Figures 3–13. As is evident in the selected patents, this research topic was focused on innovation since the end of the twentieth century:

(1) Most of the patented solutions start from using a previous structure of uprights and crossbars;
(2) Most of the solutions are designed to resolve cross conflicts between ducts and frames;
(3) No solution is focused on the insertion of an insulation panel for thermal or acoustic purposes;
(4) Most systems take advantage of the opportunities offered by cold-rolled profiles due to their folds and gaps;
(5) No concerns about reducing environmental impact are addressed;
(6) There is no consensus about where to fix sockets and switches: on board or on the frame;
(7) There does not seem to be the same interest in guaranteeing access to installations in the selected solutions;
(8) There is marked conflict between the stiffness of the walls and the flexibility of the wiring;

(9) Solutions do not seem to consider in general the opportunities presented by the wall lining in combination with a previous masonry wall;

(10) The proposed innovation does not, in general, involve the board but rather the relationship between the metal profiles and the electrical wiring;

(11) Most of the solutions present the primacy of the upright profiles, and only some raise the possibility of prefabricating all the panels in the workshop.

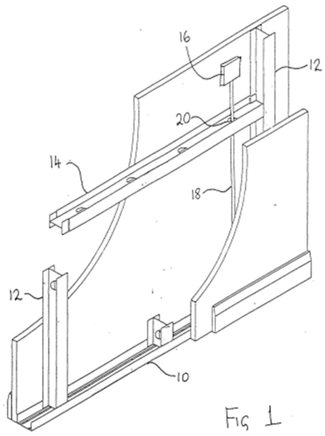



**Figure 3.** The patent [15] is designed to resolve the conflict of passage between the profile of the partition and the layout of the ducts. Reprinted from Nelson, J.A.and Pritchard, M.J. (1997).

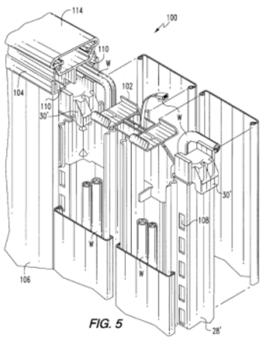



**Figure 4.** The patent [16] is designed to resolve the conflict of passage between partitions with high duct density. Reprinted from Reuter, R.E., Bullwinkle, W.C. and Reuter, R.D. (1999).

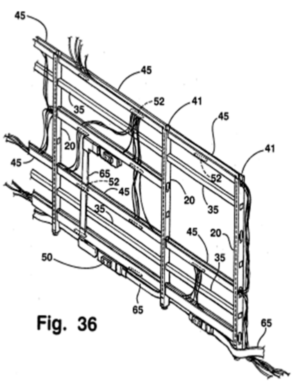



**Figure 5.** Patent [17] incorporates an intermediate panel that supports a large amount of horizontal cabling arranged on separate tracks, but at the same time, it can support control components and a track change system. Reprinted from Waalkes, M.; Pressnell, M.; Slager, M.; Shields, M.; Kane, B.; Christopher, R.; Boyle, D.; Seiber, C.; Skillman, P.; Chang, J. and Hand, R. (2007).

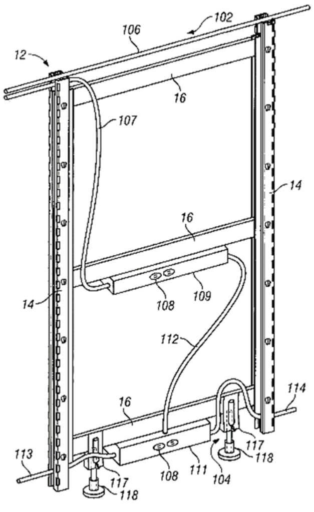



**Figure 6.** Patent [18] is an evolution of the previous patent (Figure 5) and was designed to be more easily removable or prefabricated due to the expansive leg system. Reprinted from Parshad, D.; Woronecki, P. and Liu, I. (2011).

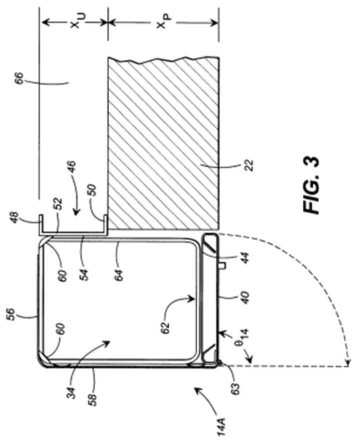



**Figure 7.** Patent [19] is designed to have cable channels that do not protrude from the plane of the partition and can be accessed. Reprinted from Wild, R.L. (2001).

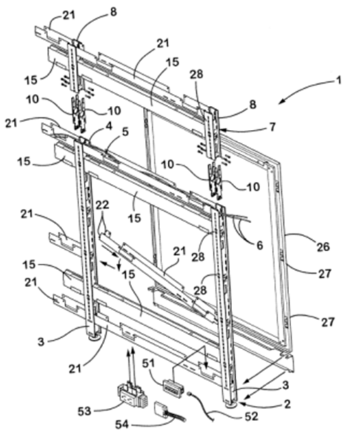


**Figure 8.** Patent [20] is designed to have a wiring support panel made from modular pieces that can be paneled. Reprinted from MacDonald, D.B.; Sanders, S.E. and Dykstra, J.R. (2002).

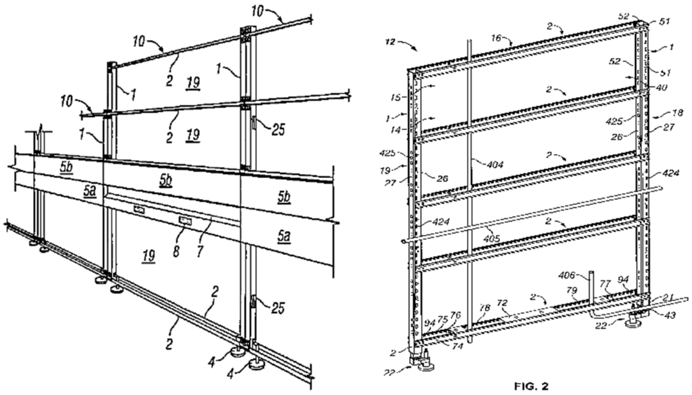


FIG. 2

**Figure 9.** Development of both patents [21,22] was perfected in later years, keeping the support system on the ground but improving the assembly and paneling system to bring it closer to the efficiency of office systems. Reprinted from Parshad, D.; Edwards, J.R.; Woronecki, P. (2013) and Liu, I.; Parshad, D.; Woronecki, P. (2013).

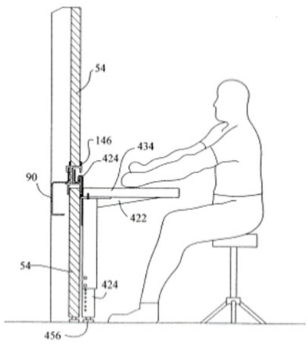


FIG. 47B

**Figure 10.** Patent [23] is designed to make the solution more specific to the office market, as furniture and partitions form an integrated whole. Reprinted from Henriott, J.M.; Metcalf, K.E. (2011).

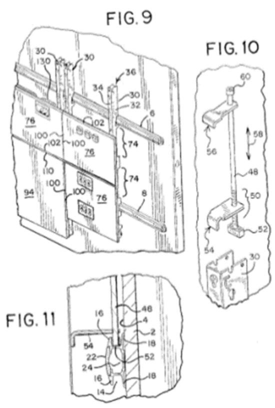
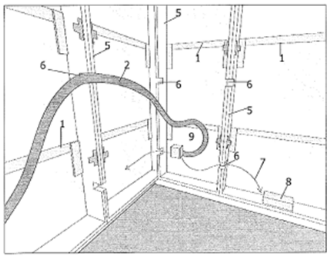



**Figure 11.** Patent [24] is designed to facilitate access to wired installations through a system of modular panels that integrate control and connection accessories. These panels are joined by a hanging system. Reprinted from Bates, M.; Boyce, A.J.; Kang, C.M.; Katje, M.J.; Lyons, S.R.; Porter, K.E.; Roetman, J.D.; Sellers, P.L.; Zaccai, G.D. (2011).



Figur 3

**Figure 12.** Patent [25] is designed to develop a partition from laminated wood profiles. Properly planned incisions should facilitate the passage of cable housing without weakening the partition. Reprinted from Baier, H. (2012).

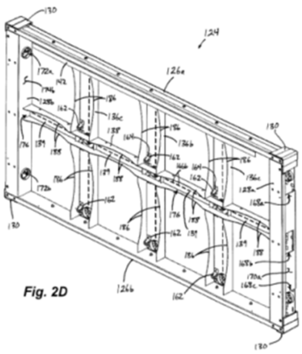



**Figure 13.** Patent [26] is designed to develop an aggregate and freestanding panel to accommodate all the elements of a wired installation that can be completely prefabricated in a workshop. Reprinted from Sutton, T.A.; Bodkins, N.J. (2012).

In the industrial market, some recent products for wall cladding make interesting contributions and point in various directions for future evolution:

(1) Internal panels that continuously support the finished board, such as NATURBO® [27];
(2) Lighter internal panels with great ease of cutting on-site, Schlüter® KERDI-BOARD [28];
(3) Systems with a modular presentation, in which the combination of two liners generates a partition wall AABYAA® [29].

Internal molded panels should solve the issues of contact with the laminate base gypsum board and contact with the supporting wall. The alternative system is wall lining of the type called semi-direct. In this case [30], the current standard specifies the type of fixings and the distances between them, but assuming that the connection between the laminate base gypsum board and the supporting wall is made through a metal profile.

As a result of financial support for the VALTEC09-2-0032 research project, some concept tests could be carried out with real market procedures in a pilot study to delimit aspects specific to the implementation, which are not well enough represented in technical literature. These include resource consumption, yields and drying times.

The consulted industrial references indicate that the challenge has not been satisfactorily resolved to date, and there are several unexplored avenues of innovation that could be of use in the challenge presented here.

## 3. Objectives of the Investigation

Considering the state of the issue, it is clear that there is no efficient solution for home wiring refurbishment from an industrial and environmental point of view. Because of technical and social needs, the current technical solutions for wall lining need to be reconsidered and redesigned to include the requirements listed below.

Before on-site works:

1. Time, cost and quality adjustments, due to increasing industrialization and modulation;
2. A reduction in environmental impact through using recycled materials.

During on-site works:

3. A reduction in run time and low waste generation through using small modules that are stackable and light;
4. Facilitation of work processes through using materials that are easily cut, nailed, screwed, drilled and fixed on the existing support and to each other;
5. Facilitation of the fitting of wired networks;

After on-site works:

6. Improvement in the final technical quality of the set without altering the initial architectural appearance: facilitation of the fitting of standard laminate base gypsum board as a finishing layer;
7. Facilitation of the fitting of thermal and acoustic insulation products.

## 4. Methods

To carry out the above objectives, a redesign process (Figure 14) was initiated to define an alternative to the wall lining air chamber based on:

(1) Replacing the differentiated support elements (uprights) with a continuous structure should reduce the thickness of the gypsum board that finally coats the liner;
(2) Looking for a recycling material with low environmental impact to materialize this continuous structure;
(3) Providing this continuous structure with relief gives it greater rigidity and the ability to insert the wiring without needing to use point fixings.

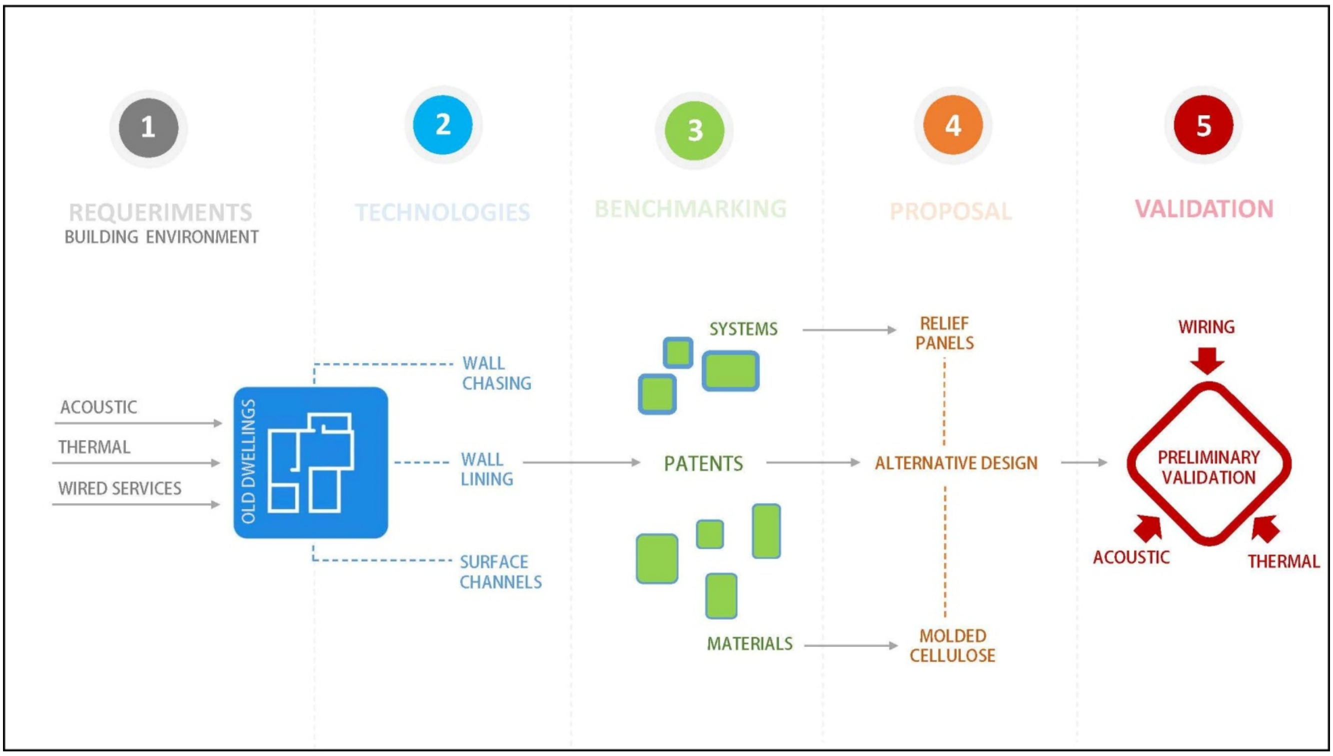



**Figure 14.** Product development methodology.

The redesign process was developed as part of a university product development workshop [31] in which students and teachers are trained and collaborate in this discipline through the design learning processes.

### 4.1. Find a Material That Meets Objectives 2, 4 & 7

The process involved looking for a material that can be formed into a panel with relief that is also machinable. Polymers are the best-positioned materials today in terms of variety, cost, precision and experience in the electrical sector. However, as they have a recognized environmental impact, an alternative solution was sought that was organic, reduced the environmental impact and recovered some industrial waste and its recycling. This research process was initiated at our own university to establish development synergies.

In this case, cellulose pulp is a good candidate. Recent innovations have been made in this family of recycled materials that have updated mechanical and waterproofing performance [32,33]. The authors have focused on *Biprocel*, a new material developed by a company that emerged from the Universitat Politècnica de Catalunya (UPC) as a result of a research project on the transformation of paper factory waste. In 2011, the patent was published internationally, and the project became a spinoff.

*Biprocel* is a suitable material [34] for this application because it can be molded easily to offer the right geometric surface to carry out its function as an interface panel between laminate base gypsum board lining and a wired network, and it can be obtained in different densities according to the applications.

This material reduces the environmental impact because it is made from recovered fiber waste in paper factories and self-recovery of construction companies' on-site residue. This new material recovers residues that are considered non-repellent (inks, loads and glues), and all the water used in their processing is recyclable. Sometime ago, a joint research development project [35] explored the possibility of applying cellulose pulp molding technologies to building materials.

### 4.2. Find a Molded Form That Meets Objectives 1, 3, 5 & 6

To define realistically what the thickness goal of the alternative system should be for wall lining interior partitions, it was noticed that this dimension was directly established by the thickness of cast sockets and switch mechanisms manufactured by the electrical industry, which are usually 50 mm. If the thickness of the alternative system fits 50 mm, it will be easy to use the innovation in the building process without extra works for adaptations.

To explore what might be the most appropriate way to meet the requirements and at the same time move closer to the current possibilities of the pulp molding technique, the search was repeated in the patent databases mentioned above. A total of 22 patents covering the period from 1949 to 2013 were analyzed. The research was completed with the study of samples that are currently present in the retail market for food packaging and household appliances (Figures 15 and 16).

From the analysis of these sources, the following findings were collected:

(1) The thickness of the cellulose pulp moldings is similar to that of cardboard paper and does not exceed 1mm, so it acquires its rigidity due to the double relief on both sides obtained from a central core. This central core also has slight ribbing;
(2) The relief, conical trunks or prismatic trunks have a slight inclination to facilitate demolding;
(3) At its edges, it is always additionally reinforced by bending to prevent perimeter tearing;
(4) Most of the moldings are stackable, which significantly reduces their volume and deterioration during transport and storage processes;
(5) The thickness achieved is in most cases around the 50 mm objective set;
(6) Modular molded parts can be obtained, but it is also possible to obtain custom-made parts for special uses;
(7) Molded cellulose is compatible with wet sprayed cellulose and injected cellulose wool used in thermal insulation applications in enclosed air chambers;
(8) All collected patents and specimens feature flat ends on both reliefs to facilitate support on flat surfaces;
(9) There are no sharp edges to avoid damage to the items themselves and to people who handle them without gloves;
(10) It is not difficult to obtain polygonal or curved surfaces;

(11) A lateral union between moldings is not provided;
(12) Most of the moldings require the need to generate boxes, an aspect that is not important for use in buildings.

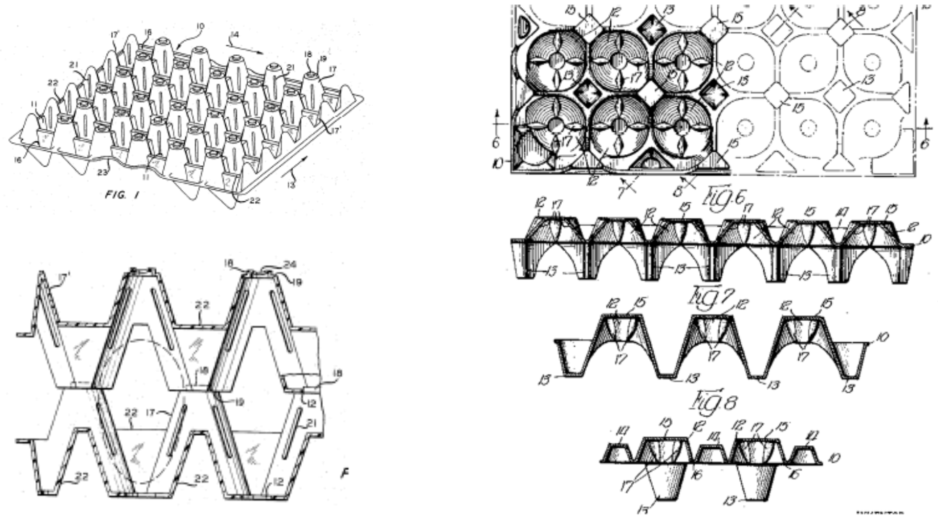


**Figure 15.** Both patents [36,37] are designed to generate a molded geometry to contain eggs in a safe upright position. Reprinted from Schechter, A. (1967). and Grant, J.R. (1953).

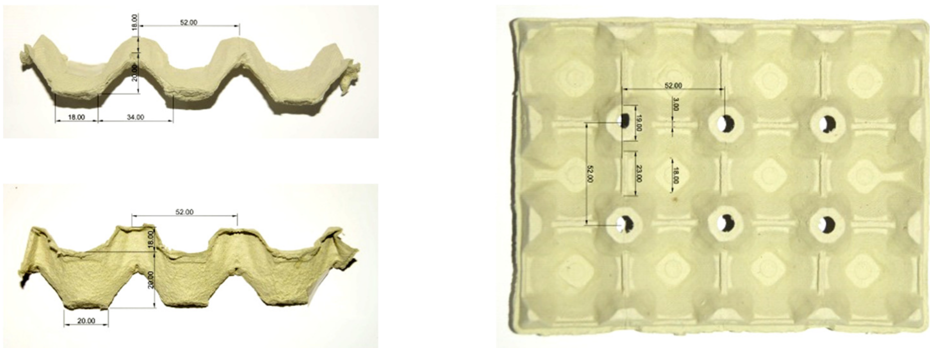


**Figure 16.** Ground, lateral and sectional view of a commercially molded cellulose plate for egg storage. (source: authors).

## 5. Development of the Molded Panel

At this stage of development of the panel, the main geometric characteristics need to be defined to adapt to all the interior renovation work.

### *5.1. Modulation and Relief of the Panels*

A previous square modulation of 60 × 60 cm is adopted because it is the common format of building products designed for interior spaces. The molded panels' feature relief is formed of two types:

(1) Outputs to support the laminated base gypsum board (LGB);
(2) Channels between the outputs to facilitate the insertion and anchorage of electrical elements. Channels of diverse width are provided: channels for wiring as described (Table 2), channels for electrical control boxes (superior and inferior) and channels for electrical connection and junction boxes (Figure 17).

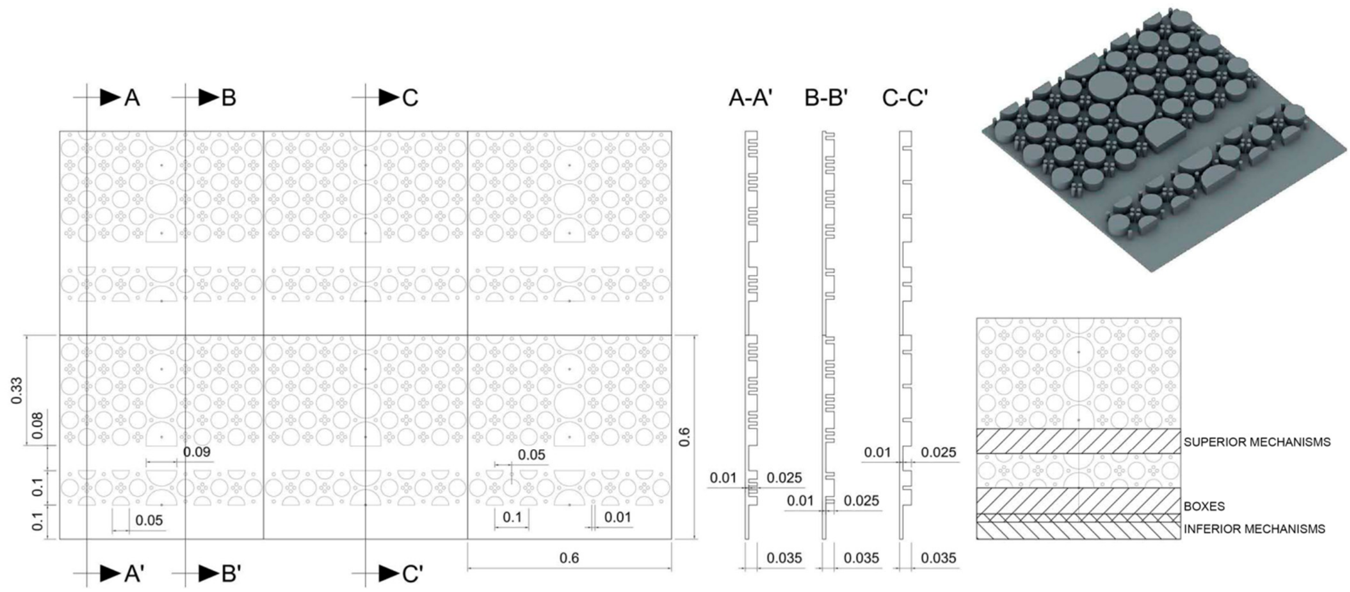



**Figure 17.** Overall view of the panel: layout of outputs and related channels. (source: authors).

## 5.2. Jointing of the Panels

To apply these panels to the surface of the previous interior partition wall, it may be advisable to start with whole panels from one corner because this will produce cutting waste only at the opposite end and close to the door openings (Figure 18). The joint between contiguous panels is created by overlapping their borders.

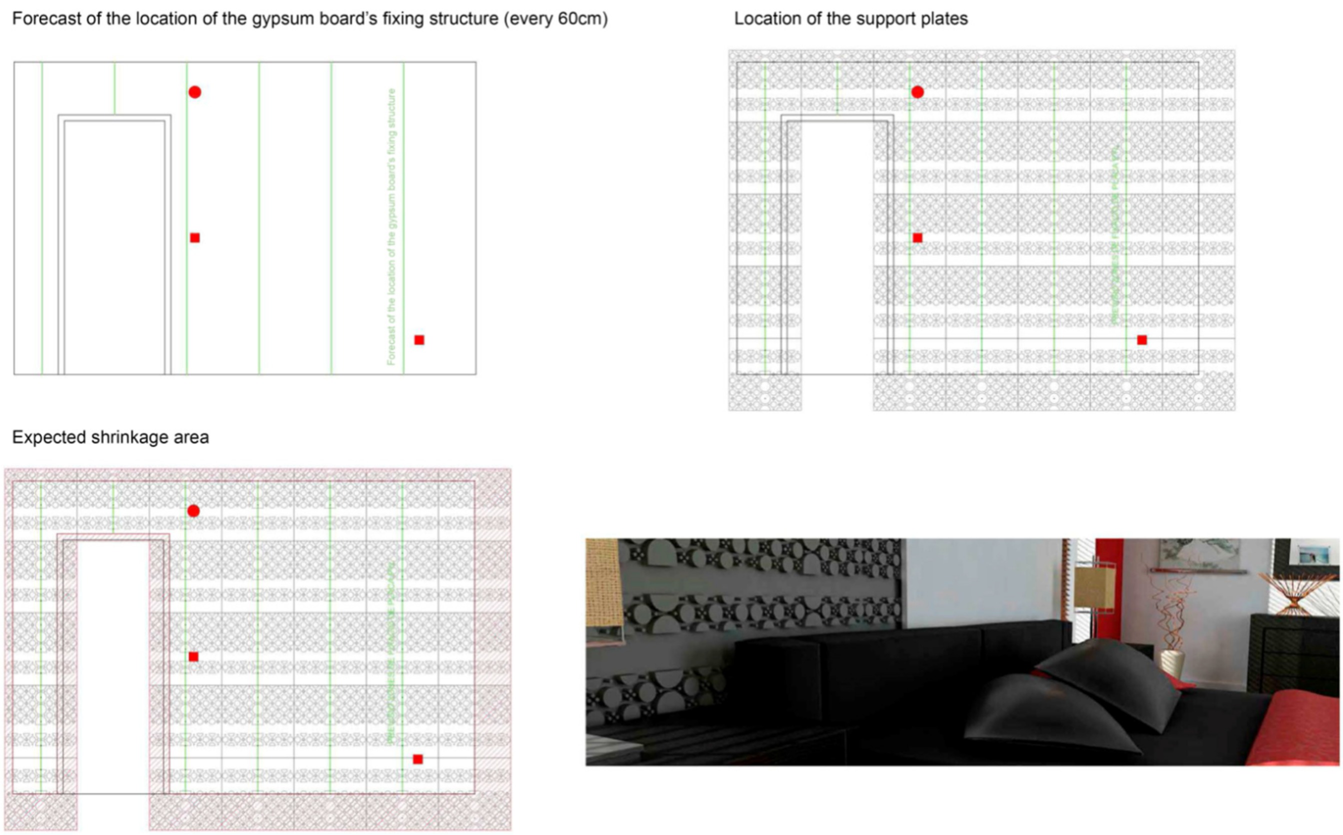



**Figure 18.** Overall view of a case application of panels on a wall. The position of the electrical mechanisms and the cutting border areas are also marked in color.

### 5.3. Insertion of Electrical Control and Junction Boxes

Electrical control boxes (switches and sockets) must be inserted tightly into the molded panel, without the need for any machining (Figure 19):

(1) 100 mm channel width for insertion of junction electrical boxes located from the lower end of the module;
(2) 74 mm channel width for insertion of switches located at 20 cm from the lower end of the module;
(3) 74 mm channel width for the insertion of socket boxes, located from the lower end of the module;
(4) The casket for fitting the mechanisms of the electrical installation is in the perimeter relief of the area designed to accommodate it.

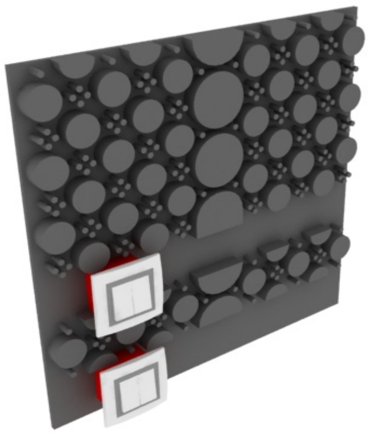


**Figure 19.** Perspective view of the location and dimensions of the switches.

### 5.4. Location of Wires

In most low-voltage electrical codes [12], the cables must be housed inside conduits in a way that facilitates their present installation and the future passage of additional cables in the future.

The basic outputs are 5 cm in diameter and are placed in diagonal, vertical and horizontal alignments. In areas where two contiguous laminated base gypsum boardswill be supported simultaneously, the outputs have an enlarged diameter (Figure 20);

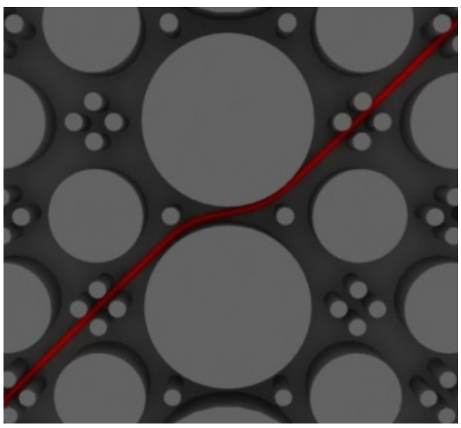


**Figure 20.** Detailed view of the insertion of a cable (red) in the different outputs.

In the free spaces between basic and enlarged outputs, there are smaller outputs to facilitate the anchorage of the wiring path.

### 5.5. Fixing Laminate Base Gypsum Board

Once the electrical wiring work was carried out and supervised, the laminate base gypsum board can be installed using the usual screw driver techniques. For this work to be easy and tight, the modulation of the outputs must coincide with the standard modulation of the laminate base gypsum board(Figure 21): line alignment of enlarged outputs (10 cm diameter) in the center of the module, with an interstice between outputs of 1cm. The prototype design evolves to adapt the previous concept design to pulp cellulose industry abilities. A preliminary geometrical model was 3D printed to test with different cable classes (Figure 22) the feasibility of the insert process.

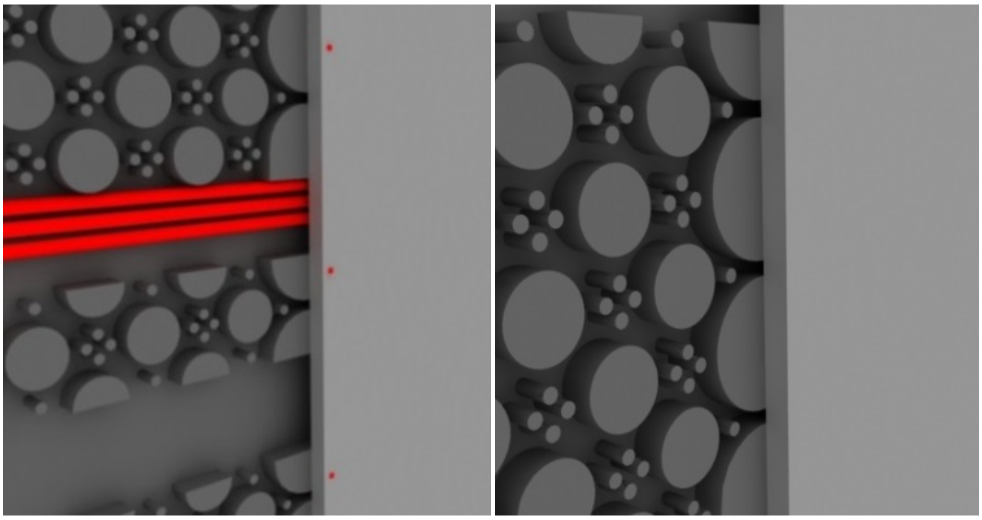


**Figure 21.** Detailed views of solutions adopted in the outputs to support simultaneouslytwo contiguous laminated base gypsum boards.

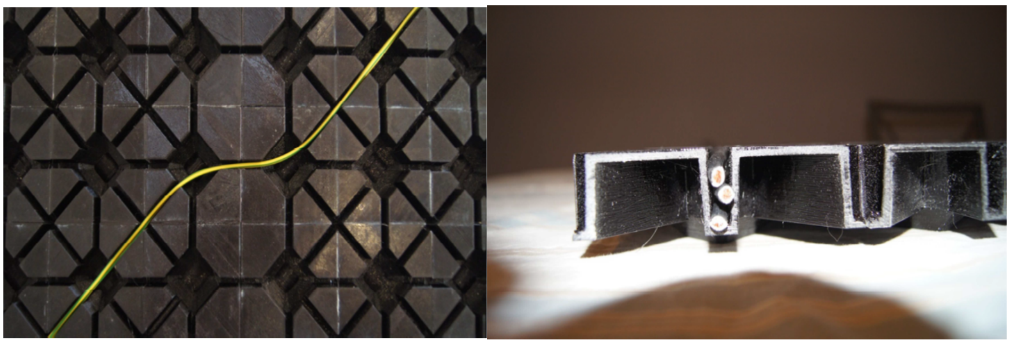


**Figure 22.** Pictures of the first conceptual model. The first prototype was made from the polymer by 3D printing.

## 6. Discussion of Preliminary Results

This preliminary prototype responds to many of the basic premises set for use in the refurbishment of building works. It is a dry process with low environmental impact, lightweight and easy to install, as indicated in detail in Section 3.

After this first step, we must continue to advance to address the following challenges of any development in the construction sector: first, proceed to adjust the parameters of strength, durability and safety, which will ensure the density and stability of the material; second, proceed to adjust the parameters in a way that is in line with the habits and preferences of workers in the sector, including wall lining professionals and wiring professionals. A third aspect is to survey electrical component manufacturers to validate whether this new support is an opportunity to incorporate greater flexibility into this subsector.

## 7. Future Challenges

After the satisfactory development of this preliminary proposal, the next challenges need to be defined:

(1) Guarantee the performance of fixing anchors between the laminated base gypsum board and the molded panel and between the molded panel and the pre-existing wall;
(2) Facilitate the mechanization and manipulation of the molded panel with single tools to facilitate insert connection and junction boxes of the wired installation;
(3) This molded panel can complement specific insulating materials that can also be derived from cellulose fiber. Non-agglomerated cellulose fiber is a type of thermal and acoustic insulation. It can be applied either blown dry or sprayed wet. It is essential to ensure the proper performance of the molded panel in contact with thermal insulation of fiber cellulose that is directly projected on the backside of the molded panel;
(4) Assessment of using boric salts to give fire retardant, fungicidal and insecticidal properties to the panel;
(5) Adjustment of the thickness of the molded layer of cellulose fibers to ensure medium-term dimensional stability;
(6) Adaption of the molded panel design to water supply ducts.

## 8. Conclusions

(1) New social, technical and environmental challenges force current construction products to evolve to reap benefits on these three fronts. The knowledge acquired in the past decades will serve as a basis for redefining current products and improving their suitability;
(2) The product design methodology can benefit the construction sector, especially in the interior rehabilitation of homes that are usually slower, more expensive and with a higher environmental impact;
(3) This research contributes to improving the applications of molded panels designed for the refurbishment and using recycled cellulose fibers in the building industry;
(4) The possibility of designing reliefs for every specific purpose is an opportunity for the future integration of home services and building elements and reducing mutual disturbance in various situations;
(5) The authors are confident that small but extensive technical problems linked to improving interior building quality, such as the one raised here, will gradually emerge. These challenges are an opportunity for co-design based on better use of existing industrial potential.

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