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DEVELOPMENTS IN RESIDENTIAL OPEN BUILDING:
Analysis and Reflections on Two Seminal Case Studies

Israel Nagore Setien, *israel.nagore@pringlebrandonpw.com*

ABSTRACT

The focus of this article is the open building concept in multi-family residential architecture. The article analyzes and examines two specific projects: the Solid Oud West in Amsterdam (2010) and the Plus Home experience in Helsinki (2005). By the analysis of these projects, the article seeks to define the state-of-the-art in open building practice, and aims to expose the possibilities and limitations that this kind of architecture offers.

The research focuses on the three main topics related to open building implementation: the possibilities of user involvement in the design process, the opportunities for an open and time-based housing design, and the benefits of an adaptable and industrialized construction. The outcome of this research seeks to inform about this trend in residential architecture and how this could affect the building industry as a whole, and architectural practice in particular.

KEYWORDS: open building, industrialization, user participation, housing, flexibility

1.0 INTRODUCTION

Open building organization is an architectural concept with growing importance in countries such as Japan, Netherlands, China, and the United States. It promotes an open and adaptable architecture aiming to fulfil the diverse and changing needs of users over time.

This article seeks to define the state-of-the-art of open building practice. To this end, it analyzes two seminal open building projects carried out in the last decade in Europe, in the specific field of residential architecture: the Solid Oud West in Amsterdam (2010) and the Plus Home experience in Helsinki (2005).

These two projects have been selected for being two of the most innovative open building projects carried out in the last decade: each of the projects has its own characteristics and they are both original in a specific way. The intention of the analysis is to expose the opportunities and limitations of the open building methodology, outlining the benefits and weak points of each project.

The article is divided in three sections. Section 2.0 explains the open building methodology and principles. Section 3.0 is the core of the research; it includes the analysis of the case studies, and reflections on the opportunities and limitations of each approach. Final conclusions and suggestions for further research are included in the last section.

2.0 OPEN BUILDING PRINCIPLES

Open building principles were first articulated by a Dutch architect John Habraken in his seminal book De Dragers en de Mensen (1962), translated and published in English as Supports: An Alternative to Mass Housing (1972)[1]. In this book, Habraken presents a paradigm shift in relation to how the housing project is conceived, that is to say, how a residential building is designed, managed, built, and ultimately occupied, pointing three key issues at the core of housing as a design problem in the 21st century: housing must be diverse, housing must accept the change and transformation, and housing must incorporate the user as part of the decision-making process.

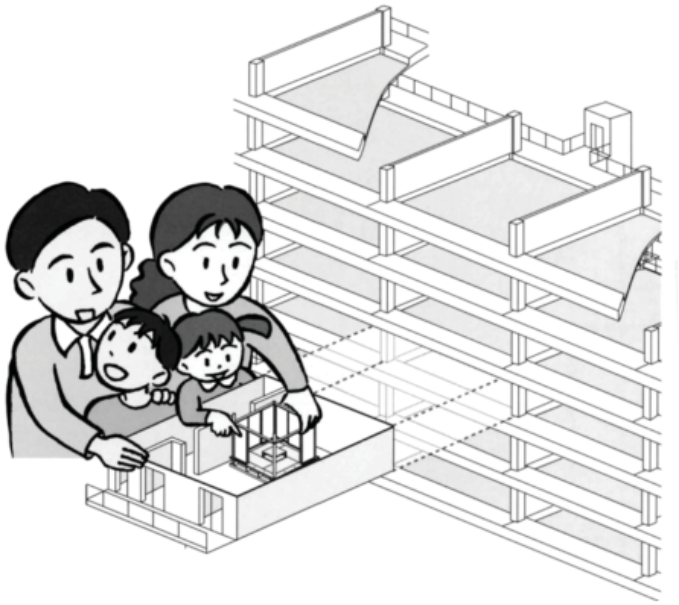

Figure 1: Support and infill separation. Image courtesy of HUDC Japan.

His proposal was based on a fundamental concept: the recognition of two distinct spheres of action and control in a collective housing building (the act of building and the act of inhabitation, separating the collective, fixed and permanent components of a residential building from components that could be transformed by individual dweller)[2]. These permanent elements - what is called the support or base building, include the structure, services, access and normally the facade; whereas the detachable units -fit out or infill- are the internal partitions, closets, bathrooms, kitchens and piping and ducts related to this equipment. Habraken proposed the separation of the design process of a residential building in two stages or construction phases. In this way, involving the user as a participant, it would be possible to respond to his/her specific requirements.

Open building proposal arises from a broader reflection on our cities and territory and it is based on three fundamental principles. The first one is the understanding of our built environment as a never-ending changing environment where buildings are transformed over time. The built environment – our buildings and by extension our cities – is a live organism, driven by rules and principles difficult to control and predict, which serves our needs through its continuous adaptation and transformation[3].

Open building principles are based on the perception of this built environment as a multi-layered structure, where five primary physical systems are recognized. Within a city, we can identify the urban structure, the urban tissue (blocks), the buildings, the infill components and the actual furniture. Each of these systems has a different life span and should be related to different levels of control and responsibility. Our built environment is sustainable to the extent that each of these systems can be transformed independently and part by part. This is the goal of open building. In short, it is about proposing an architecture able to distinguish the changeable from the permanent[4].

The second principle is based on the idea that if our built environment is to be healthy and sustainable, both users and communities need to be part of its design process. Until the 20th century, people designed and even built their houses in close collaboration with builders or skilled workers. This “natural relation” between users and built environment was broken with the modern movement -the mass housing, and the progressive “professionalization”, “institutionalisation” and “legislation” of the planning and building procedures within the last century. The appearance of new agents in the process, such as bankers, politicians, lawyers, contractors, and specialized consultants gave birth to new complex

Figure 2: Ensanche Cerda (Barcelona). Variations and transformations in the built environment. (Image courtesy of Stephen Kendall).

ways of collaborative working, which left the user out of the decision making process. The point to be made is clear: if private developers, professionals, or authorities are the only parties involved in the making of cities, the result is uniformity, where the users are excluded and cannot participate in the decision-making process related to their living environment.

The third principle is a consequence of the first two and relates to technical issues. The distinction of these two systems with different lifespan in a building (infrastructure and infill), and the requirement for equipment of the separable units, gives rise to a new sub-sector of dedicated fit-out elements. This new market is based on the open industrialization of components, which could give to the users a possibility of choice between different options of performance, quality, and cost offered by the building industry.

Within the context of a society in which major technological changes are occurring, each of the elements required in a building should be able to be changed by others. In short, it is about understanding a building as a sum of independent systems, so that each of them can be replaced and updated without affecting the others. The best example to illustrate this "technical principle" is the automobile: despite being also a complex product, its systematized production allows for the possibility of user choice and customization, as well as the continuous upgrade of its components.

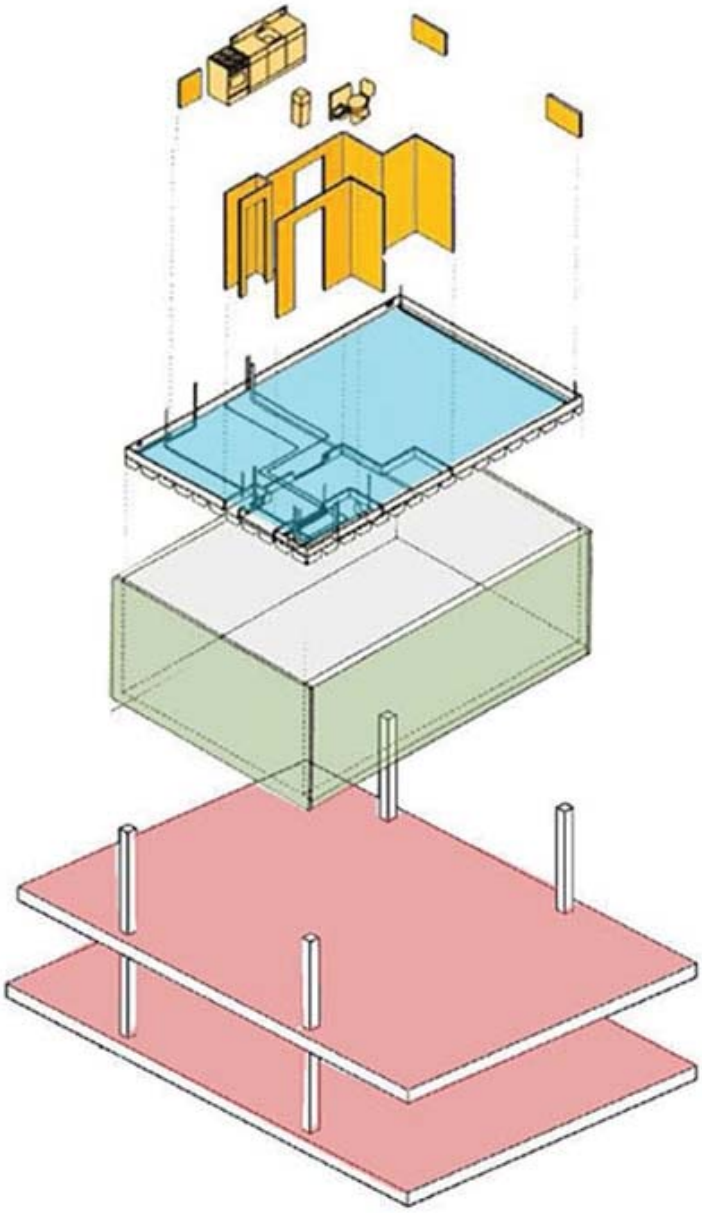

Figure 3: Separation of subsystems with different lifespan.

3.0 CASE STUDIES

3.1 Case Study One: Solid Oud West, Amsterdam (The Netherlands, 2010)

The Dutch housing corporation Stadgenoot, a non-profit private organization with links to local authorities, initiated the design and construction of the "Solids" in Amsterdam in 2010.

According to Stadgenoot, a Solid is a sustainable building constructed to be capable of lasting at least 200 years, and designed without a predetermine purpose; in fact, it should be able to accommodate any legal functionality. Solids are inspired by the 19th century New York warehouse buildings with their monumental and strong cast iron facades that are still in use today, and which for decades have been able to attract a wide variety of uses[5]. The Solid approach is based on a fundamental concept: a basic infrastructure is designed and delivered as a shell, ready to accommodate a variety of changing user-determined fit-outs over time. This enables the rented space to be designed for a whole range of purposes: living, working, cultural activities, or any combination of these functions.

Stadgenoot finished the construction of the first Solid, called Furore, in April 2011. Two other Solids were completed one month later. This article reviews Furore building, designed by the architectural practice Tony Fretton Architects. This building received the Royal Institute of British Architects (RIBA) European Award for great architecture in 2012.

Figure 4: Solid Oud West by Tony Fretton Architects. (Image courtesy of of Peter Cook and Tony Fretton Architects).

Furore is located in the Oud West district, close to Vondelpark (a central area of Amsterdam characterized by a mix of uses and never-ending activity). The complex consists of two brick constructions separated by a central atrium, which allows the access from the street into the building. The atrium connects the two volumes through the ground floor, facilitating circulation and generating a communal space. The cores are centrally located within the floor plan, connecting the ground floor with the upper levels and the garden terrace. Also, an external corridor around the atrium facilitates an alternative access to each level.

The design process was divided in two stages. The architectural task during the first phase was limited to the design of the common elements. The floor plate was then defined by the external perimeter, a neutral brick enclosure, which can accept different uses in its interior.

The structure of the building works on an eight meter column grid and is based on a precast light-weight concrete slab system, which spans from the perimeter to the central beams. This large span structural system enables a great degree of internal spatial freedom, avoiding the appearance of intermediate structural elements and facilitating an internal flexible arrangement. The generous floor-to-floor height (3.5 meters) allowed accommodation of a "thin" raised floor (about 15 centimeters), used for running wires, heating and water supply pipes, and ventilation ducts. The final three meters clear height is also suitable for non-residential uses, such as commercial and retail functions.

The final result of this first design phase was an open plan, a clear and empty floor plate that allows the users to allocate the partitions, finishes, and equipment according to their needs and economic situations.

Figure 5: Interior of Solid Oud West under construction.

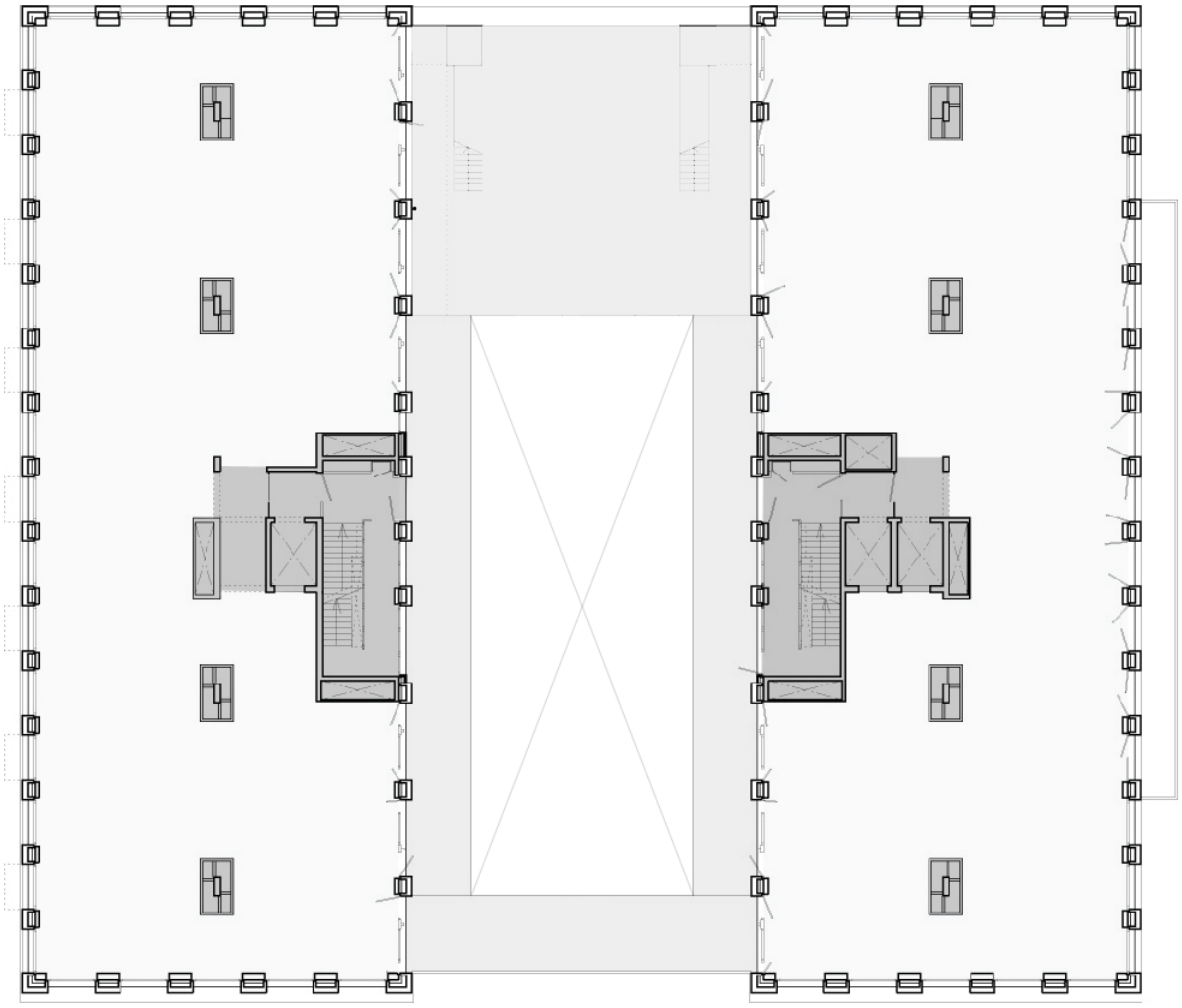

Figure 6: Solid Lv01 support plan (Image courtesy of Tony Fretton Architects).

For this second phase, the distribution of the spaces was carried out through an on-line system, where future residents chose the amount of area needed and the position of their dwelling in the complex. The challenge that Stadgenoot faced in this phase was to allocate the space in the Solids to the interested bidders. The main objective was not making profit, but to obtain a balanced functional mix between the different user types (residential, commercial, and social tenants).

The first group (residential) consisted of users who planned to live in this building, and the second group included individuals who planned to open businesses in this complex (commercial). The third group comprised low-income people (social tenants). For this purpose Stadgenoot developed a dedicated combinatorial auction system, which allowed bidders to choose the amount of space required. Therefore, the Solid was divided into 125 lots, which the residents could use and combine as building blocks to specify solid spaces[6].

Once the specific areas were assigned and the partitioning built, the flats were delivered to the users as “shells”. These “shells” were provided with the insulation and demise walls between units, but did not include any internal partitions, doors, bathrooms, kitchen, or specific equipment. The design and construction of the interior of the flat was entirely up to the dweller. The developer

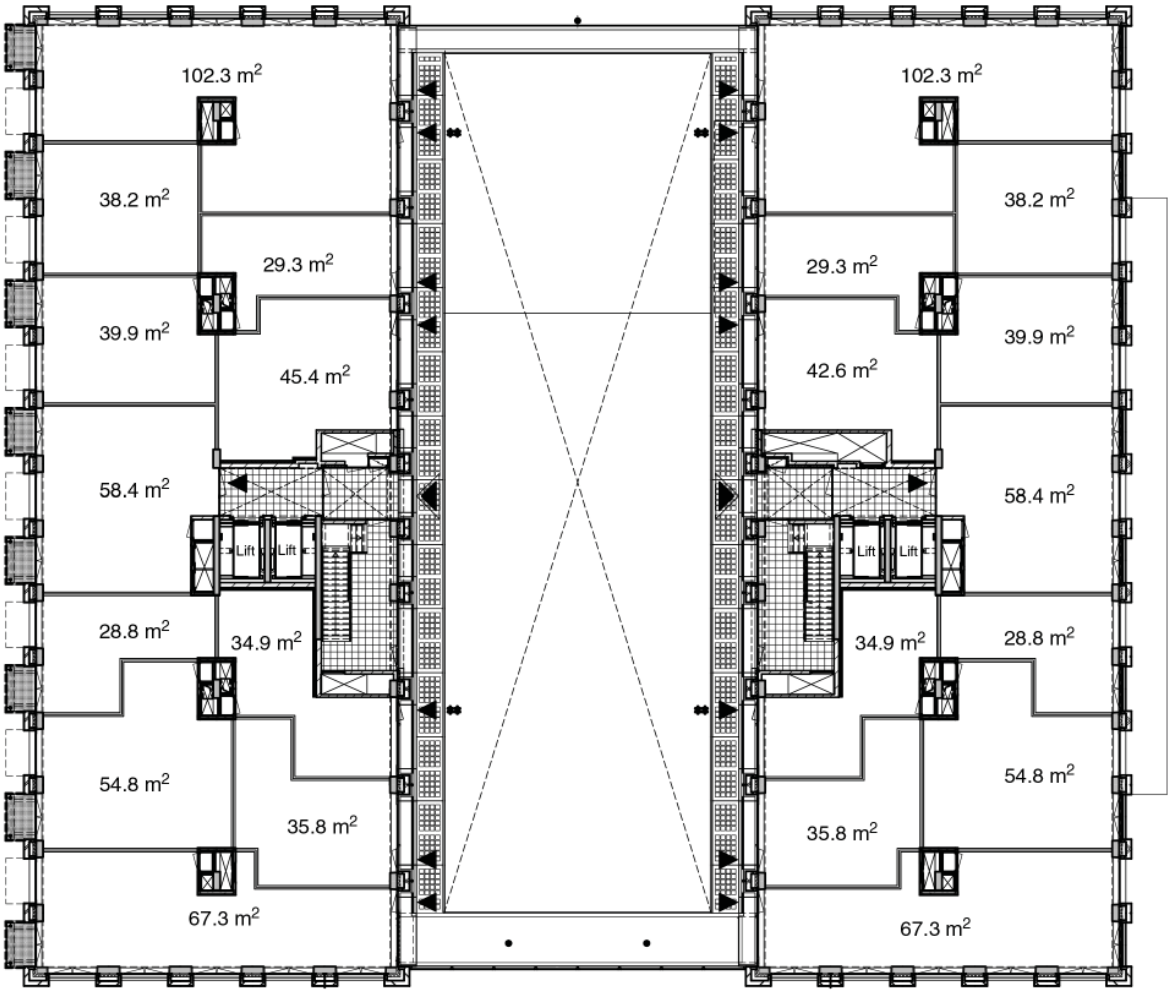

Figure 7: Solid Lv02 proposed allotment plan (Image courtesy of Tony Fretton Architects).

made available to the users different options, offering the service of suppliers of equipment, designers, and interior decorators that would propose solutions based on the user needs. Also, if preferred, the users could decide to find their own designers, subcontracting the equipment and installations.

To sum up, this two stage approach opens up a great variety of options for the users. The users can "finish" their apartments during the second phase, adapting it to their preferences and economic possibilities. This second "construction phase" can be repeated in the future, each time the needs of the users change.

From the management point of view, these two "construction phases" are associated with two levels of control and ownership. In a Solid, the developer (Stadgenoot) remains owner of the infrastructure and is responsible for the care and maintenance of the building's infrastructure. The tenants rent the infrastructure space, but is the owner of the infill unit (partitions, equipment, and finishes). If a tenant leaves, he/she can sell the interior to a next tenant. Over time, solid spaces can grow (when merged with another solid space) or shrink (when split up).

In this way, the developer recovers the initial investment based on the rents provided by the tenants over the

years. Tentative calculations show that it is realistic to assume that the initial investment in adaptability can be worthy and profitable in the long term due to the savings in maintenance costs, renovations, and subsequent transformations.

3.1.1 Residential and office buildings: Possibilities and limitations of the two step approach

Through the analysis of the Solid Oud West, the open building principles have been exposed as an alternative to conventional procedures in multi-family housing buildings. Some of these principles are actually common practices in the office and commercial buildings.

At the early stage of the planning process of an office facility, the architect focuses on the integration of four parameters: the shape of the building massing and envelope, the location of the services and the structure, the relation between internal area and the perimeter, and the position of the cores in relation to the office space. These items are carefully considered in order to provide flexibility and ensure the quality and optimization of the internal space. Also, it is worth mentioning how the distinction of these two "construction moments" in commercial and office building types - has provoked the development of a new subsector of secondary components for the subdivision of the interior spaces, such as raised floors, drop ceilings, industrialized and demountable cupboards and partitions[7].

Similarly, if the housing project was approached "as an infrastructure" without partitioning, where different dwelling types can be allocated, then the general organization of the services, the location of the structural elements and even the spatial quality of the dwellings could be better. In this case, even different options of subdivisions and non-residential uses over time would be possible. Likewise, the current technologies and construction systems used in offices could be adapted to multi-family housing.

However, the design is not the only point of comparison between residential and office buildings. The division of the process in two phases and the "control and ownership system" previously described, are also procedures which could be incorporated into a new housing management system. This system would facilitate to a great extent the diversity of occupation patterns, enabling also the possibility of change and transformation of the building over time.

The multi-family housing buildings can learn a lot from the office buildings, not as a direct reproduction of the design approaches (since this would prevent us from responding to other basic requirements and representative values characteristics of the residential architecture), but as a way to appropriate and adapt to its needs some of the irrefutable advantages that from the design, management and construction point of view, this building type offers[8].

As a whole, the Solid project was assessed as a successful experience. However, due to its innovative and experimental character, a number of difficulties arose along both the design and occupancy process. One of the challenges that the developer faced was the allocation of spaces within the Solid. Drawing a good allotment is not an easy task, specially taking into account the various constraints and requirements of each group of bidders.

Some of the constraints originated from municipal and building regulations. For instance, the stairs have an emergency rescue capacity that cannot be exceeded. The rescue capacity needed for each bid depends on the surface area of the solid space and bidder's intended function for that space. Each bid has different requirements with respect to ventilation, water, gas, and electricity (again depending on the area and the intended function). Also, the area of a solid space has size limitations depending on the use. Furthermore, a valid combination of lots must have at least one door to the central gallery and access to a utility shaft[6].

This set of preliminary parameters made the allocation process quite complex, affecting in some cases the design and quality of the spaces. Some of the final proposed lots are enclosed in tortuous shapes, including dead end spaces and corners difficult to plan as a dwelling unit. It is important that the subdivision possibilities are carefully planned well in advanced (at the base building design level) to ensure the quality of the final arrangement.

Another difficulty arose from the statutory regulation and the bureaucracy related to the "two step approach". In this type of procedures, the final layout of the dwellings is not known at the first stage and, therefore, cannot be approved by the municipality. This issue opens up the well-known debate about the inflexibility and rigidity of some the current housing regulations in relation to the size and subdivision of the dwellings. The discussion is mainly about to what extent the building code should determine what the housing unit looks like on the inside.

This controversy is caused by an external issue: the good will from the governments to control the safety and the final results, and avoid a downgrade of the habitable space (due to the use that residents could do of it if total freedom is given).

There are two options to overcome this statutory issue: to allow for a permission of post-occupation, which should be processed after the "shells" are delivered, based on the design of the interior fit-out project or alternatively to stablish a pre-planning authorization within the first phase, based on the assumption that a certain set of conditions are accomplished. Regulations in some countries are becoming more permissive in relation to the internal fit-out (such as the Netherlands), but most of the European countries are still falling behind.

The third and last difficulty arises from the need to fit out the "shell" spaces after the first phase. The separation of the construction process in two phases implies the requirement of a dedicated interior design project and the management, and fit-out construction of each "shell". Although the housing association (Stadgenoot) assisted in this respect, the reality is that there are not many dedicated companies prepared to assist in the design of the infill units as a whole package in an efficient way –due to the fact that open building is a relatively new trend. It is hard to find companies that are able to pack the parts and deliver them in the right order and pace, including qualified and skilled workers who are present at the right time to assemble them. Logistically, it is quite a challenge to get everything from the supplier to the right place[9].

John Habraken explains in relation to this issue, "the construction sector is still organized in such a way that it involves a sequence of workers. A man for the walls, one for the electricity, the plumbing, which is a lot of fuss when occupants have to organize all that themselves. With these Solids you are dealing with a consumer-oriented project. Therefore, a criterion should be: how can you make it as easy as possible for your tenants? You must search for a balance between the best possible freedom for the occupants, without burdening them with all kinds of technical and management issues[9]."

In this sense, this type of procedure should always include a manual of technical and operational recommendations, so the dweller knows how to appropriate his/her house in the second phase. That is to say, all the tools and means needed to facilitate the fit-out should be put at user´s disposal, either through technical advice or by facilitating contact to the relevant professionals and technicians. The development of specialized infill companies along the growing implementation of open building will also help in this respect.

3.2 Case Study Two: Plus Home Experience, Helsinki (Finland, 2005)

During the last two decades, Finland has been one of the pioneers and leading countries in open building implementation. The main reasons leading up to this development are the research and teaching at Helsinki University of Technology from the beginning of 1990s, and the continuous support given by both the Finnish Technology Agency and the local authorities[10].

Within this context, Plus Home experiment stands out as a fundamental example, which combines the interactive possibilities of the internet with the principles of the open building principles. This project was the winner entry for a competition organized by the municipality of Helsinki in collaboration with Tekes (National Agency of Technology of Finland), carried out in 2002. The main objective of the competition was to promote the design of housing focused on the users, incorporating the principles of industrialized construction.

Besides the architectural proposal adequate for the site and specific context, and the technical solutions that facilitate the construction of an open system, the entries for this competition had to submit a management and data-collecting process efficient enough to meet the user requirements in a direct and individual way. Therefore, the brief of the competition was formulated to promote a multidisciplinary approach: architectural practices, developers, and data processing companies had to work together from the conceptual stage.

The winner entry was SATO PLUS HOME, a team formed by SATO-company as the leader and investor, Kahri&Co Architects as the main designer and ToCoMan Group as the cost, data, and internet consultant. The project was selected for the best new building in Finland by Finnish Association of Civil Engineers in 2005, with the main characteristcs of "remarkable architectural, structural, social, and ICT merits."

The site of the competition is located in Arabianranta Shore, a new residential development close to the seaside, five kilometers from the centre of Helsinki. The Plus Home proposal included two six-story high buildings, accommodating 77 apartments from 39 to 125 square meters, as well as retail, workspaces, and com-

Figure 8: Plus Home, Arabianranta Shore (Image courtesy of Esko Khari and Esko Enkovaara).

mon areas for the community on the ground floor. Each block is 14 meters wide, with stairs facing north to allow access to the apartments. Whereas the north elevation is made of brick with a regular composition of windows, the south façade is made of glass with generous open terraces to make the most of the sun and heat gain during the summer.

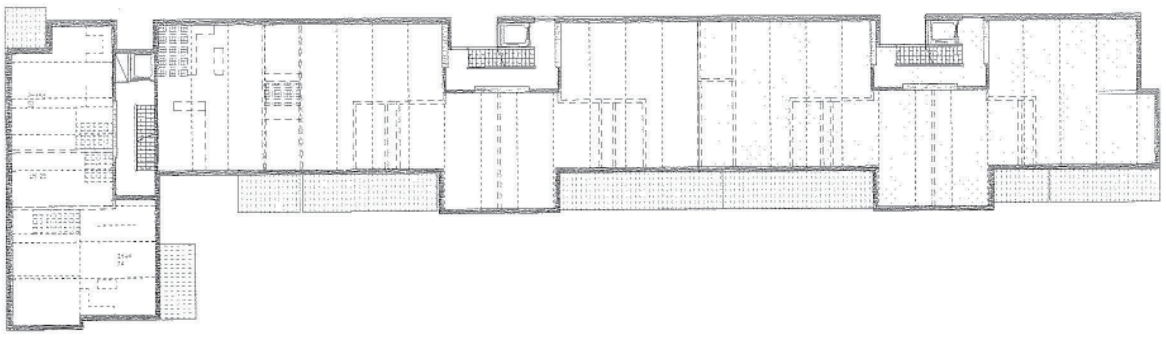

Figure 9: Typical level, support plan without subdivisions (Image courtesy of Esko Khari).

Figure 10: Typical level (cores B- C), support plan without subdivisions and Infill plan showing arrangement of apartments (Image courtesy of Esko Khari and Esko Enkovaara).

In order to enable the variety of housing types and the future adaptability, the construction of the building contained features in line with support and infill principle, which differs from the traditional way of building in Finland. For example, the load-bearing walls are located in the envelope of the building instead of in the cross-walls between the apartments in order to provide a flexible space for varying layouts on different floors. The load-bearing structure inside the walls is steel columns at maximum three meters intervals. Connected to the columns are Z-formed steel beams, which bear the concrete slabs.

Figure 11: Offsite manufacturing of load-bearing walls minimizes the construction time on site (Image courtesy of Esko Khari and Esko Enkovaara).

Most of the slabs are concrete hollow-slabs of about 10 meters span. The steel-framework makes possible to prefabricate the walls in large elements. This makes construction on site very quick. Also, the construction work is dry with very little in-situ concrete casting, which is favorable in this type of climate.

For the sanitary spaces, a two-layer slab was used, which allows flexible plumbing. The floor structure in these "wet zones" was "upside down", where the concrete slab was placed on the bottom of the steel beams, allowing plumbing and ventilation ducts to be freely positioned depending on the floor plan, after which a wooden floor layer was installed on top to close the floor cavity.

All internal walls are built in light construction with piping outside of apartments, to allow later change. The walls between the apartments are light construction with double frame, insulation and double plasterboards. The electric installations are made using an open distribution profile on the upper part of the partition walls, which provides flexibility and enables the adding of service networks.

The facade design consists of steel-structured external wall elements with almost unlimited window placement and many types of outer facing on site. The exterior is of red brick or clad with thermal plastering, some parts of profiled metal plate. The balcony slabs are made of concrete with concrete filled steel pillars. The balcony façade has an ever changing appearance, reflecting the individual variety of the residents[10].

Apart from the construction features, Plus Home was innovative as a pioneering experience in mass housing customization principles and the implementation of advanced IT and data management procedures. Tocoman, BIM software company, was part of the winning team, and developed a dedicated server tool that was accessible by all the agents involved in the project. This platform worked as the pivoting axis for the project, and included two subsystems: a BIM modelling software (Archicad) used by the design team and an interactive online system that allowed the participation of the future users.

In this manner, the architects worked together with the quantity and cost consultants on the design of the building using BIM, taking into account materials, quantities, costs, and user decisions. In this way, it is possible to keep all the documentation and data of the project centralized and not spread in different places, avoiding different versions of the same information and instantly recognizing any modifications.

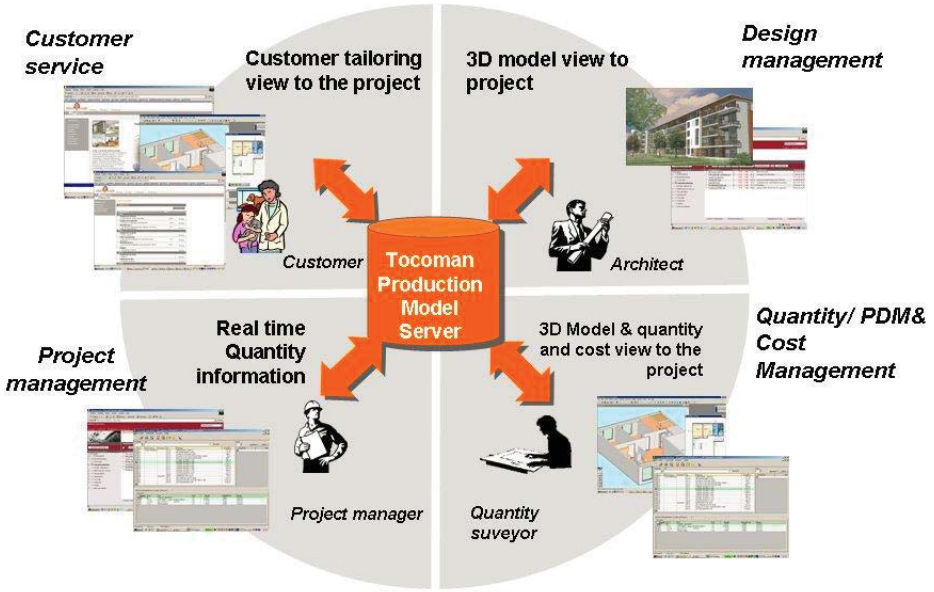

Figure 12: Plus Home, data and internet services software (Image courtesy of Esko Khari and Esko Enkovaara).

This model server enabled the coordination of the project and design process, while the residents could simultaneously start choosing between alternative floor plans in the pre-marketing stage via the internet. This online decision making process was managed by means of a five-step system, which allowed the users to personalize their dwellings. The customization started with a wide selection of floor plans offered, in terms of location of the apartment and sizes within apartments. Also, for each size, there were three possible layout arrangements, in which the position of the services and the rooms varied.

Moreover, the system allowed to choose different options of materials, finishes, and equipment. The options for a fixed price included the wood floor and the tiles with three and four alternatives for each option. In the case of the bathroom, users were able to choose among different options of color tiles and materials. Also, the glass for the windows could be selected[10].

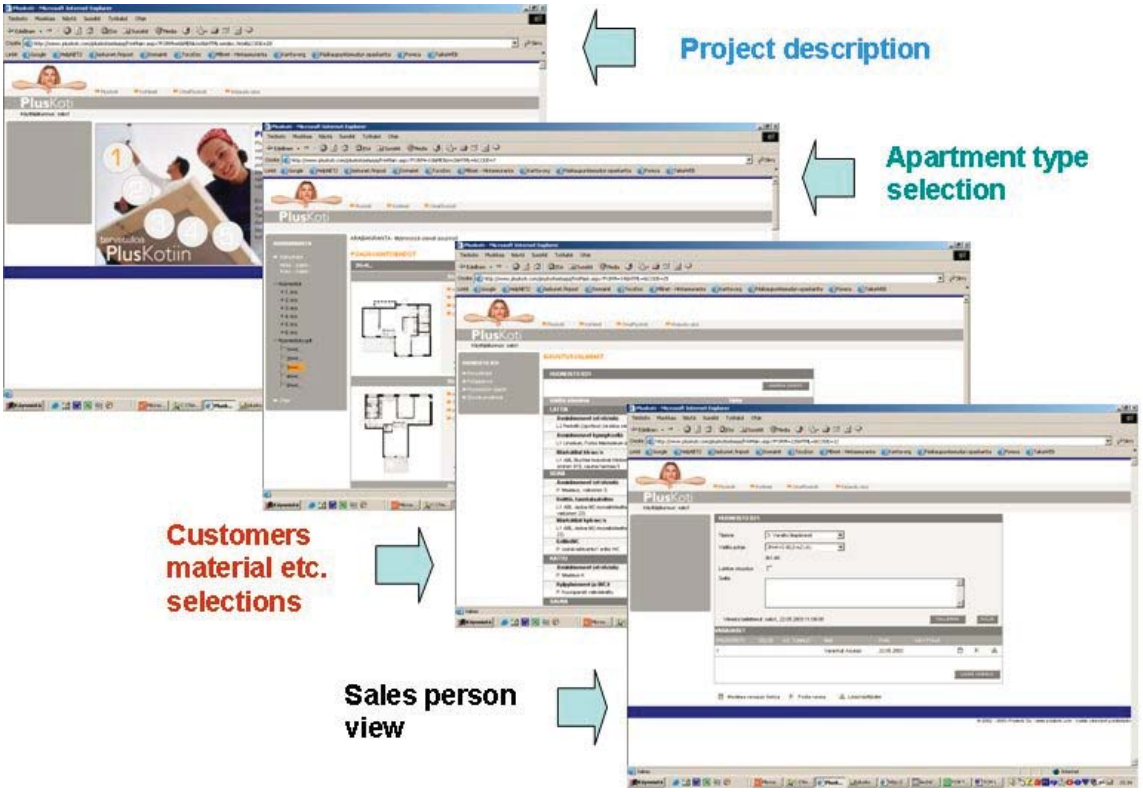

Figure 13: Plus Home, data and internet services software (Image courtesy of Esko Khari and Esko Enkovaara).

This stage was open until six months before the construction started. Then the building was completed with floor plans according to customer's choices. After this stage, the residents had three months for the final selection of surface materials, fixtures, and accessories with fixed prices. Each of the decisions and modifications later in this phase were registered in the model of the building.

In this way, the buyers could see the total price of their apartment directly after making their choices, and could also revise their choices. Once the user has finally selected all the options, the final plans, quantities, materials, and costs were available for the quantity surveyor, builder, developer, architect, and providers[10].

The Plus Home experience was a successful project. The SATO Group outlined a strategic plan concerning open building principles in 2005, using this concept for all their production of owned apartments. Since 2006, several projects have been carried out following these principles.

3.2.1 The new ways of participation: Possibilities and limitations of the Plus Home experience

During the last few years, one of the key achievements of informatics in relation to architecture lies in the capacity to optimise and organize the building processes. New BIM software programs already announce what may be a new paradigm. The use of this type of software has been limited so far (with exceptions) to the coordination work of architects, engineers, project managers, contractors, and quantity surveyors. However, few projects such as Plus Home have entered the ground of user involvement, including the users as participants in the design process.

The potential of these tools may be of great help to avoid the standards that prevent the industry from offering specific and customized solutions for each user (mass housing customization). As shown in the case of Plus Home, it is already possible to work with online platforms to optimise individual solutions at different levels of design, being worthwhile and not impacting deadlines, costs or extra-efforts for the developers[11].

In Plus Home, the mass customization principle had to allow for a certain level of standardization: the apartment sizes and their variations were pre-planned, as well as the interior selections (equipment and materials). This is at the moment, the only way to manage affordably customer choices and variations. Hence, it is required to agree to a certain level of standardization beforehand, in order to build the project data structures.

This can be seen as one of the limitations of the project: the system has its own rules and user involvement was limited to the selection process system. Further research may be needed to consider opening up the range of possibilities in a more flexible set of rules, which can be controlled in terms of cost and project management, giving the user a chance to impact the design of his/her dwelling within a wider spectrum of parameters.

Furthermore, the new technologies already offer the possibility to participate within the collective elements. By means of the social networks or the development of specific online platforms, it already seems feasible to establish internet relations with future neighbors, to agree disparities in relation to the brief and budget, the internal management of the community and the common spaces, to provide transparency to the process or even collaborate with the inhabitants of the adjacent buildings. All this could help to generate community feelings even before occupying the building physically[11].

4.0 CONCLUSION

This article analyzed two approaches to open building concept. Both case studies share characteristics in line with outlined principles: the open design strategies respond to time-based architecture, they include users as participants in the design process, and rely on industrialized and adaptable construction. Moreover, they both have compelling start-up processes in common: one project used an auction and the other used the internet.

Within these similarities, they have a different approach in relation to the support and infill separation, which turns into a fundamental difference at the organizational level of the project. In the Solids, the accommodation process was divided in two phases, with all the implications at the contractual, management, and statutory levels. In Plus Home, this separation remained just as a concept informing the design and construction throughout the project: the infrastructure and infill were conceived to be physically different construction elements, but the building process stayed as a single conventional stage.

In terms of future adaptability, both approaches are valid since the support and infill distinction at the construction level can enable flexibility in the long run. However, they offer different opportunities in relation to the first occupation of the building: in Plus Home, user participation is limited to the choice between options at the early stage, whereas in the Solids the users can have total control and freedom over the design of their dwelling, since a dedicated fit-out project is required in the second phase. This fundamental difference makes the Solids “more open”, both in terms of level of user involvement and the capacity of adaptation to non-residential uses.

In this respect, the Solids are innovative and truly ground breaking in putting forward the two-step approach, which sets the scene for the recognition of two levels of control and decision making in the residential project. As advocated by the Open Building movement, the recognition of these two levels of control is fundamental in order to achieve a sustainable built environment, able to be transformed part by part.

As a down side, it is worth mentioning some of the difficulties that arose during the project delivery due to the lack of experience in this type of procedures where the two stage approach is adopted. Further research based on realized projects may want to consider the development of methods and tools to overcome these milestones.

Plus Home, on the other hand, deals with the topic of user participation in a more limited way within a single stage conventional process, but it is original and compelling in relation to the used data and management system and the implemented technology. These aspects made it possible to respond to users in an efficient and individual way, enabling at the same time the coordination and cooperation of all parties involved in the building process. The analysis shows that further research could be done in relation to the possibility of loosening up the constraints limiting the user choices and the possibilities of participation at the collective level.

To sum up, we can state that each project is revolutionary in its particular way. Therefore, they should not be considered as rivaling or directly comparative, but as accumulative or combinative. This shows that the pos-

sibilities that open building principles offer are diverse. As shown in the analysis, to make the most of them will require adapting the housing production process (in terms of design, management, coordination between building agents, legislation, and statutory procedures), to the requirements of this new methodology. But, also it will depend to a great extent on the actual will of the parties involved in the process (authorities, developers, contractors, and designers) to make the users participants in the design process of their living environment.

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