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The construction by strata. Techniques and strategies of the modern project (1923-1945)

La construcción por estratos. Técnicas y estrategias del proyecto moderno (1923-1945).

Ruth Arribas-Blanco (*)

ABSTRACT

The influence of industrialization on architecture in the first half of 20th century changed architects' way of working, who resorted to industrialized products to create an architecture characterized by Construction by Strata. New strategies were put into practice and the role of technique became something more than simply resorting to new materials or advanced industrialized technology. The aesthetic component became an inherent aspect of the building itself and was always subtly present to reflect the consistency with which the objective criteria of scientific methods were used. The main objective of this research is, using the case method, to analyze, from a technical and constructive point of view, the new project strategies that emerged at the beginning of the 20th century from the appearance of new paradigms, as well as to demonstrate the creative capacities of the construction process itself and check the current validity of the identified strategies.

Keywords*:* modern architecture; industrialization; prefabrication; technology; project strategy; Georg Muche; Bauhaus; Gerrit Rietveld; De Stijl; Jean Prouvé; Marcel Lods; Richard Neutra; Rudolf Steiger; Konrad Wachsmann; creativity; materialization; sachlichkeit.

RESUMEN

La influencia de la industrialización en la arquitectura de la primera mitad del siglo 20 modificó el modo de trabajar de los arquitectos, quienes recurrieron a productos industrializados para crear una arquitectura caracterizada por la Construcción por Estratos. Nuevas estrategias se pusieron en práctica y el rol de la técnica se convirtió en algo más que un simple recurso a nuevos materiales o tecnologías industrializadas avanzadas. El componente estético se convirtió en un aspecto inherente al propio edificio y siempre estuvo sutilmente presente para reflejar la coherencia con la que se utilizaron los criterios objetivos propios del método científico. El principal objetivo de esta investigación es, utilizando el método del caso, analizar, desde un punto de vista técnico-constructivo, las nuevas estrategias de proyecto surgidas a principios del sigo XX a partir de la aparición de nuevos paradigmas, así como demostrar las capacidades creativas del propio proceso de construcción y verificar la vigencia de las estrategias identificadas.

Palabras clave*: arquitectura moderna; industrialización; prefabricación; tecnología; estrategia de proyecto; Georg Muche; Bauhaus; Gerrit Rietveld; De Stijl; Jean Prouvé; Marcel Lods; Richard Neutra; Rudolf Steiger; Konrad Wachsmann; creatividad; materialización; sachlischkeit.*

(*) PhD en Arquitectura. Profesor asociado. Univeristat Politènica de València (España).
Persona de contacto/*Corresponding author*: rarribas@cst.upv.es (R. Arribas-Blanco)
ORCID: http://orcid.org/0000-0002-1886-1402 (R. Arribas-Blanco)

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1. INTRODUCTION

The role of the technique and his influence in the architectural field at the beginning of the 20th century has been considered to reflect on how architects experienced a change of attitude and accepted his responsibility in a task in which new variables came into action.

During the previous centuries, the machines had been emerged, but they were incapable of making the decisive changes to conceive the new society characterized by the industrialization. The new advances and the technical possibilities were not yet expressed in the architecture of that time. It was an architecture anchored in the past; an architecture unable to reflect the *Zeitgeist*. On the contrary, the engineering works, as Muthesius already had said in his intervention in the VI International Congress of Architects that took place in Madrid in 1904, reflected the progress of the industry as early as the second half of the 19th century. A few days later, Berlage also said, referring to the aforementioned Muthesius conference, that the progress of architecture should be entrusted to the application of recent industry achievements and to constructive logic (1).

In this context, Exhibitions were a singular event as a showcase for the technological advances produced in the fervent emerging industrial sector. The Universal Exhibitions took place mainly in the second half of the 19th century. In 1881 it was held in London. For this occasion, the admired Crystal Palace was built, whose originality did not lie in the materials used or in the resolutions of the vault, but in the "new relationship established between the technical means and the (…) expressive aims of the building" (2). In 1889, after having been organized innumerable exhibitions in different European and American cities, one of the most impactful events due to the construction of the *Galerie des Machines* and the *Tour Eiffel* took place in Paris. Both constructions were a clear manifestation of the possibilities offered by the technique and of the way in which the engineers knew how to use it with great mastery.

The new materials and the progress achieved after the Industrial Revolution favored the development towards modernity initiated by engineers, through the construction of large pavilions, passages, galleries, bridges, so snatching the hegemony that the architect had sustained until that moment. It took time for Architecture to react, while engineering works already showed without complexes the possibilities offered by technique. As Gideon explained, "construction is unconsciously moving towards aesthetic sensibilities feeling which did not find their equivalents in art and architecture until decades later" (3). In this depressing atmosphere, deprived of all creative spirit, Henry Petrus Berlage was able to see beyond and build a construction that marked the future of 20th century architecture. Opposed to "fake" architecture, in which the general trend was imitation, with the construction of Amsterdam Stock Exchange he managed to defeat the prevailing eclecticism and materialize a building in which he chose to show with shameless sincerity the way in which it had been built. Using brick as the main material, the load-bearing structure exhibited without complexes the path that the loads followed through the walls in a bare space that stood out for its compositions based on pure volumes.

This path of purification had been initiated previously in North America. There formal simplicity prevailed in every production process, from household tools and utensils, whose shape was indebted to the material and techniques used and which responded to the function for which they were created, to imposing industrial buildings. An it was there, in the United States, where a new way of manufacturing based on mass production emerged a few years later, which was a revolution at the time. Henry Ford, influenced by ideas of Frederick W. Taylor and of Frank B. Gilbreth was the one who popularized manufacturing through the assembly line in the automotive industry. A way of producing through the assembly line that inevitably influenced the internal organization of the factory itself, modifying their configuration, as a result of close collaboration between architects and engineers, such as that carried out by Albert Kahn in Highland Park for Henry Ford in 1909. In Europe, Germany was one of the countries where the principles of Taylorism and Fordism were subsequently applied more intensely in the field of industry, in general, and construction, in particular, promoting mass production and standardization in order to achieve an improvement in productivity (4).

European architects were fascinated by American technique. However, they considered it anonymous so they wanted to add the *Kunstform* to the *Technikform*. That is to say, "Americanism, characterized by the affirmation of technology, of perfect rationalization and absolute modernity, should therefore be ennobled by European culture, following the rules of the *Werkbund"* (5), whose principles would continue in the *Staatliches Bauhaus* by Walter Gropius, where art and industry merge, which is in essence, architecture and technique. In that context, Peter Behrens, for instance, defended the fusion of art, as intuition and psychic impulse (*Kunstwollen*), with technique, understood as a tool and not as an ultimate goal, in the conception of any object, be it a work of engineering or a product obtained from industry. In this way, he was looking for new forms that reflected the new spirit of the time and were capable of expressing the very nature of the object. However, the general trend was not yet to project considering the constructive aspects and their influence on the final form. In fact, as M.A. del Val exposes, the mistake of dissociating the constructive criteria from the aesthetic ones, in other ways, emancipating or detaching the technique from the forma, referring them to two different spheres of architecture as if they were independent of each other, had its peak 1929 around to what happened in the controversial contest for the Headquarters of the League of Nations. The victory of an academicism that was in its last days generated a confrontation between two sides (6). As Christian Zervos points out in the manifesto published in the *Cahiers d'art*, "it is about struggle between the old and the modern" (7), of the attempt to perpetuate tradition with progress, of the ghosts rooted in bourgeois eclecticism against the prevailing spirit of the New Architecture that was been born for the people. Despite the triumph (first prize ex-aecquo) of the project carried out by the Jeanneret cousins, as well as the third prizes obtained by Hannes Meyer, finally the dispute was settled with the construction of a building that nothing responded to what was happening in the society of the moment.

Although in the exposed example they suffered a controversial failure, the project criteria used by the architects assigned to progress (rationalization of space, use of standardized construction systems, elimination of superfluous, use of scientific parameters, as well as the consideration of the function of the building) were gradually managing to imposed themselves as principles of nascent architecture, given the evidence of the paradigm shifts that were taking place. It was the dawn of the twentieth century, years in which the break was evident between the architects adhering to the formalist side of architecture versus those who were fierce defenders of the role of construction, when the predominating voices who considered that any self-imposed formal limitation should be overcome, emerged, proclaiming the interaction between the two.

Technique and aesthetics became two complementary and coexisting facets of the same intellectual process. The tectonic dimension of architecture took on the leading role; construction found its rightful place in the creative facet and became leading character within the final configuration of the project and its materialization (8). As stated by M.A. del Val (6):

> The construction is thus configured as a component of first magnitude (...) to such an extent that it can be said that a project does not exist if it does not contemplate its own realization.
>
> That is why there cannot and should not be a confrontation between form and construction, because both are adjusted from the beginning of the project through a relationship with the technique that endows architectural arguments with the stability with which reality presents what is necessary and not random.

Thus, at a time characterized by the great technological and scientific advances that have taken place, these had, without doubt, also an enormous impact on the architectural discourse and on the materialization of ideas itself. Further, using again the words of M.A. del Val (6), "it is necessary to note that a return to construction does not mean the simple gathering of diverse materials (... and that) construction should be valued as a projective discipline and technique as a real control of design". That is, the execution of project ideas must be considered as an opportunity to enrich the discourse and be used, therefore, as a creative tool with which to develop architectural projects.

2. CASE STUDIES

The new paradigms caused by the irruption of industrialization and the application of science, especially mathematics and physics, affected "both to the very conception of architecture as well as to the entire process of its realization (design and material), introducing as a priority value of this thought the norm of efficiency" (9), that is, "the search for maximum benefit from minimum cost in the construction or in the workings of the buildings" (10). This is what is known as *Sachlichkeit* or objectivity, referring to "any concept in which a work is implicitly carried out with accuracy" (11). These paradigms were mainly responsible for the change produced in the approach when facing the architectural project, analyzed from two different scopes and both related to the tectonic dimension for architecture: on the one hand, production and, on the other hand, organization.

Throughout this research, it has been investigated how, from the new ways of producing and organizing, new strategies have appeared that have influenced in different aspects of architecture: Form, Structure, Material, Component, Space, Function. Their most important characteristic is that all have a relationship with a new way of working that was still generally limited to a simple intuition of what be done, considering that incipient technology was still at the embryonic stage. Experimenting was the principal way of tackling uncertainty for someone who trusted their instinct as opposed to following certainties, far from travelling along the safe path of tried and tested methods.

The strategies identified have been: *Reproduction, Liking, Manufacture, Assembly, Tuning, Gearing*; each of these is a consequence of a change in paradigm. And the buildings considered as case studies, in regard to the aforementioned strategies, have been: *Stahlhaus* (1926, Georg Muche and Richard Paulick), *Mobilar Structure* (1939, Konrad Wachsmann), *Maison du Peuple* (1935, Jean Prouvé), *Plywood Model House* (1936, Richard J. Neutra), *Chauffeur's House* (1927, Gerrit Th. Rietveld), *General Motors Suïsse assembly factory* (1936, Rudolf Steiger).

It is necessary to highlight that the selected projects have been chosen for their characteristics that make them pioneers within the corresponding approach to which they refer, giving preference to second-rank projects within the Architectural History to vindicate their importance. It is also necessary to emphasize that the important thing in this research is not the projects themselves, but the strategies used in them, so that other could have been used instead.

All the works correspond to the same space of time, considered the years 1923 and 1945 as a turning point. The choice of these dates corresponds to events of certain significance within architectural history. 1923, the year in which the experimental house Haus am Horn was built at the Bauhaus, can be recognized as the beginning of the application of industrialization on the architectural field. On the other hand, in 1945 dates the beginning of John Entenza's program, Case Study Houses, at which time the architecture of the beginning of the century had already reached its fullness. These years therefore mark a period in which the importance of the projects lies in their precursor character at a time when the technique still offered few possibilities, compared to those belonging to the second modernity or orthodoxy, in which it was finally able to confirm the insights put into practice in previous decades. The difference between the projects of one period and the other one is found in the initiating and experimental nature of the former, which represented a true break with previous tradition, as opposed to the continuing character of the latter.

2.1. Form: Typified reproduction (Stahlhaus)

The shortage of housing was one of the main problems at the beginning of the 20th century when, Walter Gropius, thanks to a commission to build accommodation for the working class in Dessau, was able to put into practice his ideas on rationalization, standardization and mass production. These were principles which until that moment he had not been able to carry out, but he had been developing and perfecting over the years in different texts and theoretical proposals[1]. The methodology used in the construction of these dwellings cannot really be considered as a novel method nor can it be said that it would mean a great advance in the world of prefabrication. However, as Herbert stated, "the concepts of standardization, mass production, specialization of labor, mechanization of operation and rigorously planned organization of labor and materials, which are the characteristic features of the industrial system" appear here and it allowed a reduction in the construction time (12).

1 Some of them were: Programma zur Gründung einer allgemeinen Hausbaugesekkschaft auf künstlerisch einheitlicher Grundlage, m.b.H. (1910), Wabenbau (1922), Buakasten im Großen (1923).

In 1925, simultaneously with the construction of the first phase of the *Siedlung* Dessau-Törten, a steel house (*Stahlhaus*) designed by Georg Muche and Richard Paulick was built. This was done as an experiment for the inauguration of the new Bauhaus headquarters in Dessau. The principles used were those of the Bauhaus workshops, where the concept of handwork and industrial production were closely related. It was necessary to first discover the object-type that would fulfill the initial premises in such a way that it could subsequently be produced in large quantities by the industry. That is to say, artisanal activity ceased to be and end in itself and became a method of learning for the individual (13).

The *Stahlhaus* (fig. 01) was projected as a typified reproducible artefact whose shape was a conjunction of its functionality, the used technique and economy. A way of doing that had been already used, for example, by Alma Siedhoff-Buscher in her children's furniture (14). Shape, like style, was replaced by the search of the essence, the *Wesenforschung*. In this way, the maximum simplicity to simplify the typing of the object for mass production was sought.

Stahlhaus can be considered as a prototype realized to experience the industrialized construction of houses using prefabricated elements (15). For the execution, Muche and Paulick proposed their own constructive method based on special cross-sectional profiles and standardized components. However, finally, it was decided to use the standardized construction system of the company Carl Käster a.g. (16).

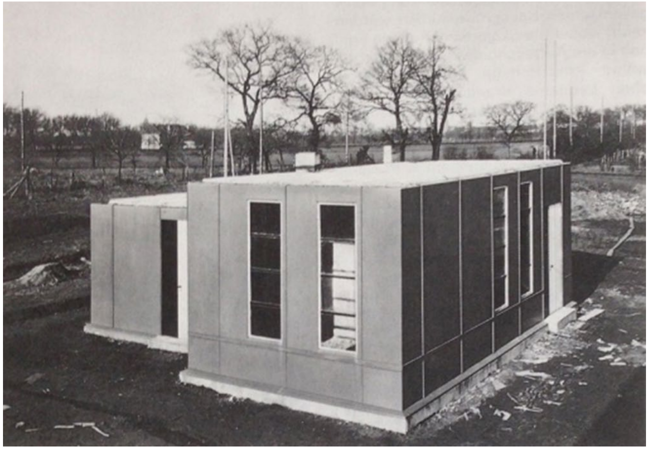

Figure 1: *Stahlhaus* during its construction. Source: Engelmann, Ch. and Schädlich, Ch. (1991). *Die Bauhausbauten in Dessau*. Berlin: Verlag für Bauwesen.

The main achievement was the creation of an object built by mechanized techniques and with easily reproducible final form, which represented the essence of the intrinsic qualities related to its function and the building method used. And, consequently, it had an innovative aesthetic that had nothing to do with what was done so far. The dwelling thus became an industrialized consumption product, i.e. the final commodity within the productions process. It was studied to guarantee its efficiency, quality and economy. It had become a typified object with a considerably reduced final cost, since it was being mass produced and sold in large quantities, in the same way as Ford Model-T cars.

2.2. Structure: Three-dimensional mass production (Mobilar Structure)

The development of three-dimensional frameworks took place, initially, in the world of civil engineering due to the need to solve greater distances between supports and to withstand much higher loads. These were structures that had evolved from initial configuration of two-dimensional elements repeated successively by configuring a framework whose static behavior could be calculated in easier ways either by graphic or numerical methods.

It's important also mention that, in 1903, Alexander Graham Bell had already published a text in which he showed his experiments on three-dimensional kites and his conviction about the importance that the structural shape had in the stability and resistance in this kind of structures made with tetrahedrons (17). In fact, Konrad Wachsmann, a self-taught German architect, recognized Graham Bell as a pioneer in the mass production of standardized tetrahedrons prefabricated from metal bars with which he obtained very simple three-dimensional kite-structures whose construction would have been much more complex if it had been made using conventional means (18).

Wachsmann put these ideas into practice by developing some projects, such as the well-known *Packaged House System* and others like the *Mobilar Structure* that evolved to the USAF hangars, once in the USA. These projects were generated from a three-dimensional modulation, under a spatial conception, which facilitated the use of standardized elements produced in large quantities. Specifically, *Mobilar Structure* system can be summed up "in a nodal point o connector where perpendicular lattices converge with each other, and annexed surfaces that function as

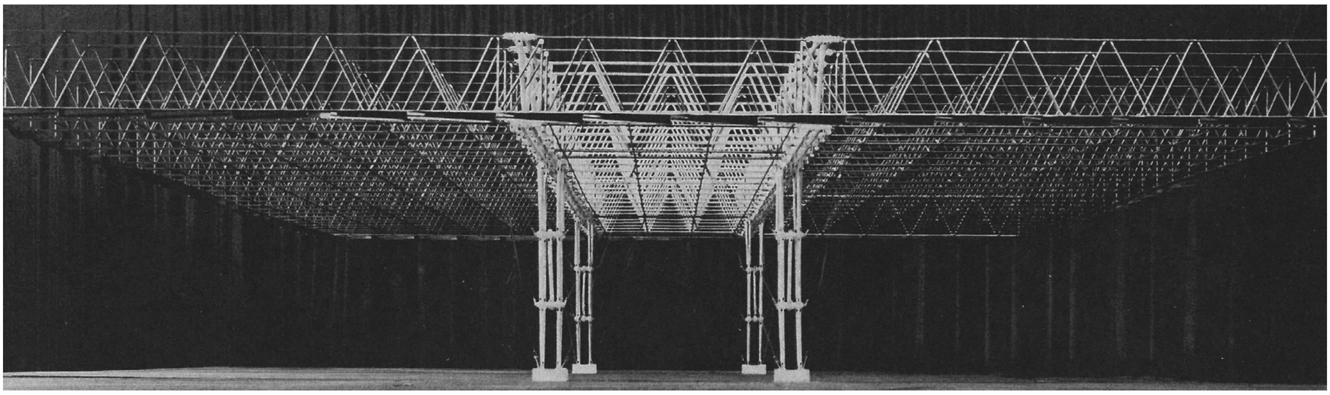

Figure 2: Model of *Mobilar Structure System*. Source: Arribas-Blanco, R. (2016). Jean Prouvé and Konrad Wachsmann. Two ways of using the scale model as a tool for projecting. *Proyecto, Progreso, Arquitectura*. 15, 56-69.

mobile enclosures" (19) and was conceived to use standardized elements with predefined dimensions characterized an open-plan modulated space. The resulting architecture was a three-dimensional construction that could be indefinitely extended (fig. 02). The hangar could have any dimension and shape, depending on the number and position of modules used. The integral construction, consisting of a continuous roof and mobile independent walls, was also designed along with its disassembly and easy transportation. The connector was a fundamental piece that acquired a double technical and aesthetic function that, in a theoretical way, evokes Gottfried Semper's knot. As Wachsmann himself stated: "they are not only point of contact, but they also describe with the greatest precision the object they surround; it does not have only a determining aesthetic value, but they are the result of technical functions and these have to be considered" (18).

With this way of proceeding, the project and building processes had to maintain a continuity and involved the use of scale models to give a better control of all the parts distributed around the space. The design of the connector and the tubular elements were the key to the project's process, since success depended on them. They allowed the transformability of the construction and the joining of components, as well as guaranteeing a good static behavior.

These networks or molecular structures based on the repetition of their "cells" can be observed on some architecture whose morphology is a consequence of the strength diagrams in their own structures and where stability is achieved through the triangulation of their configuration. Constructions in which the architectural form is identified with the structure. The conjunction of bars from any spatial direction generated an isotropic space. Constructions originated by means of spatial repetition that followed a crystalline distribution. The result was "an ordered structure that embodies the generating laws and the parts as a whole" (20). That is, a three-dimensional construction that is identified with macro-form and that, through the combination of molecules or microforms, generated an architecture that was space in itself, being the way in which these particles were arranged through weaving the space what mattered (cause) and not the resulting form (consequence). For Wachsmann it was more a matter of technology.

2.3. Material: Efficient production (Maison du Peuple)

At the beginning of the 20th century the book "On Growth and Form" was published, which greatly influenced both artists and architects, as well as engineers and biologists. In this book D'Arcy Thompson argues that the form of living beings can be explained using mathematical and geometric concepts, as well as physical laws. He also linked the concept of efficiency defined by Galileo with the 'structure' of living beings, asserting that they adopt their most effective form depending on the efforts that they must endure. He continued with two issues that he considered of great importance and that were directly connected with the effectiveness of the structures. The first one consisted in how Nature arranges the material increasing the thickness of the section in those areas subject to the greatest tension, while reducing the section in the least requested areas. In the second question he explained that the traction and compression lines are identical and symmetrical between them, joining both systems to support the loads to which the corresponding section is subject. However, he claimed that it was also possible to weaken one of the systems as long as there was a compensation from another. As if, for example, we ran a rope with two distant points whose section presents all tension lines, but no compression ones. In this way the importance of the material and how it responds to the actions to which it is subjected based on the capacity it has to resist traction or compression was found.

Although there have not been any direct references or testimonies that confirm that Jean Prouvé knew of existence of this book, however, there are statements made in first person in which the French constructor claimed that his best source of information was found in the contemplation of nature: "look, like the thumb to the hand. Everything is well done, it is solid, they are form of equivalent resistance and, despite everything. They are flexible" (21). Prouvé always spoke of equivalent resistance, without differentiating whether the design corresponded to a piece of furniture or a building, referring to the shape acquired by the objects that he projected and constructed. It was the response to requests to which they were subjected, being more resistant wherever that had to endure an effort. An unquestionable similarity is reflected here between Prouvé's equivalent resistance and D'Arcy Thompson's effective form.

The professional training of Jean Prouvé was closely related to the making of things. The design of furniture had a fundamental importance in the evolution of his work, as it was already affirmed by A. Guiheuz (22) and N. Foster (23). In all his creations, regardless of the scale, he used the same logic based on economy, constructive simplicity and material optimization. A representative example is the way of configuring the top board of a table whose resistant component coincides with that of *Roland Garros Aeroclub's* roof in which the elements subjected to bending have greater magnitude. Or in the case of *Maison du Peuple*, which, as its author indicated, resembles "a kind of large stool" (21). This is one of the most important projects carried out by Jean Prouvé during the 1930s in collaboration with the architects Beaudouin & Lods and the engineer Vladimir Bodiansky. The folded sheet was the main material that characterized the construction. This building was created as a complete object and conceived from the overall efficiency of the unit. This determined both the production method and, consequently, the final shape (24). This can be observed in the envelope of this building. It evolved through different stages where the joint (fig. 03) had a leading role. Jean Prouvé, using prototypes, designed several alternatives. He worked the shape of the folded sheet to obtain a solution that met all requirements, such as wind resistance and preventing the entry of the water.

In this building everything was made to fit. Full scale prototypes fabricated with the same materials as the definitive parts were used to test the effectiveness of the system, as in the case of an automobile chassis or an aircraft fuselage. The architectural object was produced industrially, but not using industrialized components but by being manufactured like other industrial products, i.e. with the same variables of efficiency and economy that govern industrial production. The final shape of each elements was a con-

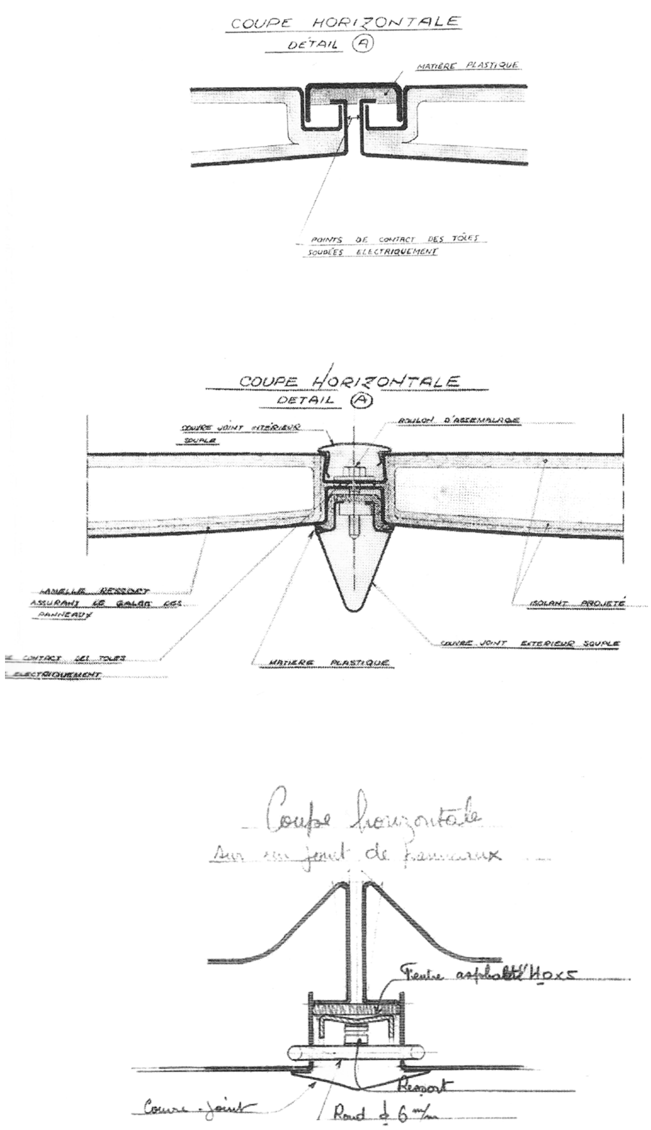

Figura 3: Evolution of the joint between facade panels in the *Maison du Peuple*. Source: Dumont d'Ayot C. Nad Reichlin, B. (Eds.). *Jean Prouvé. The Poetics of the Technical Object*. Weil am Rhein: Vitra Design Museum.

sequence of the raw material selected for it. The material and its optimization were the protagonists in this project strategy.

2.4. Component: Adaptable assembly (Plywood Model House)

In a North American context, where industry was practically non-existent, mechanization was introduced as a substitute for skilled labor, unlike the way it did in Europe. The standardization of pieces was one of the first consequences, which was, intimately related to the interchangeability of the same. In the United States, the commercialization of products also increased in the absence of the limits established by customs. It can be relatively easy to imagine, in this scenario, the impression he made on Richard Neutra an "industrialized technology of the United States, exact but repetitive" (25).

It can be said that manufacturers of buildings components played a key role in the development of architecture in the early twentieth century in the US, in this framework, it is inevitable to mention the popular American publication known as *Sweet's Catalog*. This was a big influence for the American architects of that time, who today are considered of relevant importance in architectural history, such as Albert Frey or the abovementioned Richard Neutra. And as stated by Neutra himself, while in Europe "much or all of its production had a 'special', almost artistic character" (25), in North America, the middle class had many products manufactured industrially for the construction of their houses.

The Lovell Health House, one of the first made in the USA with a totally metallic structure, was conceived to be a living machine composed of standardized pieces that, according to Lamprecht, was "a tribute to the Sweet's Catalog" (26). The use of catalog elements showed a different way of dealing with the construction process. The structural component lost importance next to the catalog elements used. The wall was to be 'technified' becoming a succession of elements finished in the factory that overlap and juxtapose, composing the different enclosures.

Other lesser-known projects in which the use of industrialized parts was decisive were the proposals presented in the General Electric Small House contest organized nationally in 1935. In them it can be seen that Neutra contemplated the possibility of interchangeability between the wooden structure derived from the traditional balloon frame and a structure made with light metal elements. As he himself explained (27):

> True enough the new materials, the steel skeleton, for example, were first to open a fresh vista onto possible use of large glass areas, and the new heating devices now increasingly permit their use without losing control of the room climate. But old venerable wood construction has nevertheless no difficulty of following suit and partaking in the new spirit. The designer in Wood can easily enough divorce himself from a primeval way of thinking.

Even though none of the two proposals presented were built, there are enormous similarities between one of them and a project built a year later for an exhibition, in which he thoroughly developed the construction system proposed in the abovementioned contest. This project is known as *Plywood Model House*. In this case, he used again a material newly added to the market, plywood, which until that moment could not be used outside. He chose a balloon-type structure with 4-inch squared wooden columns that were prepared with grooves to receive the metal joinery. They were separated between them a distance with coincided with the space needed to install the windows. The result was an anonymous architecture in which the importance dwelled on the simplification of the process derived from the use products supplied straight from the industry and not in the constructive detail. All the possible encounters between the different components were studied and each element fulfilled a specific function within the whole, whose sum's purpose was the overall efficiency of the system (fig. 04).

Richard Neutra gradually developed a cataloguing system for the details brought about, which he used indiscriminately in his projects (28). Far from being innovative and original, in his projects he adapted the standard details and repeated them constantly. To reduce possible problems during

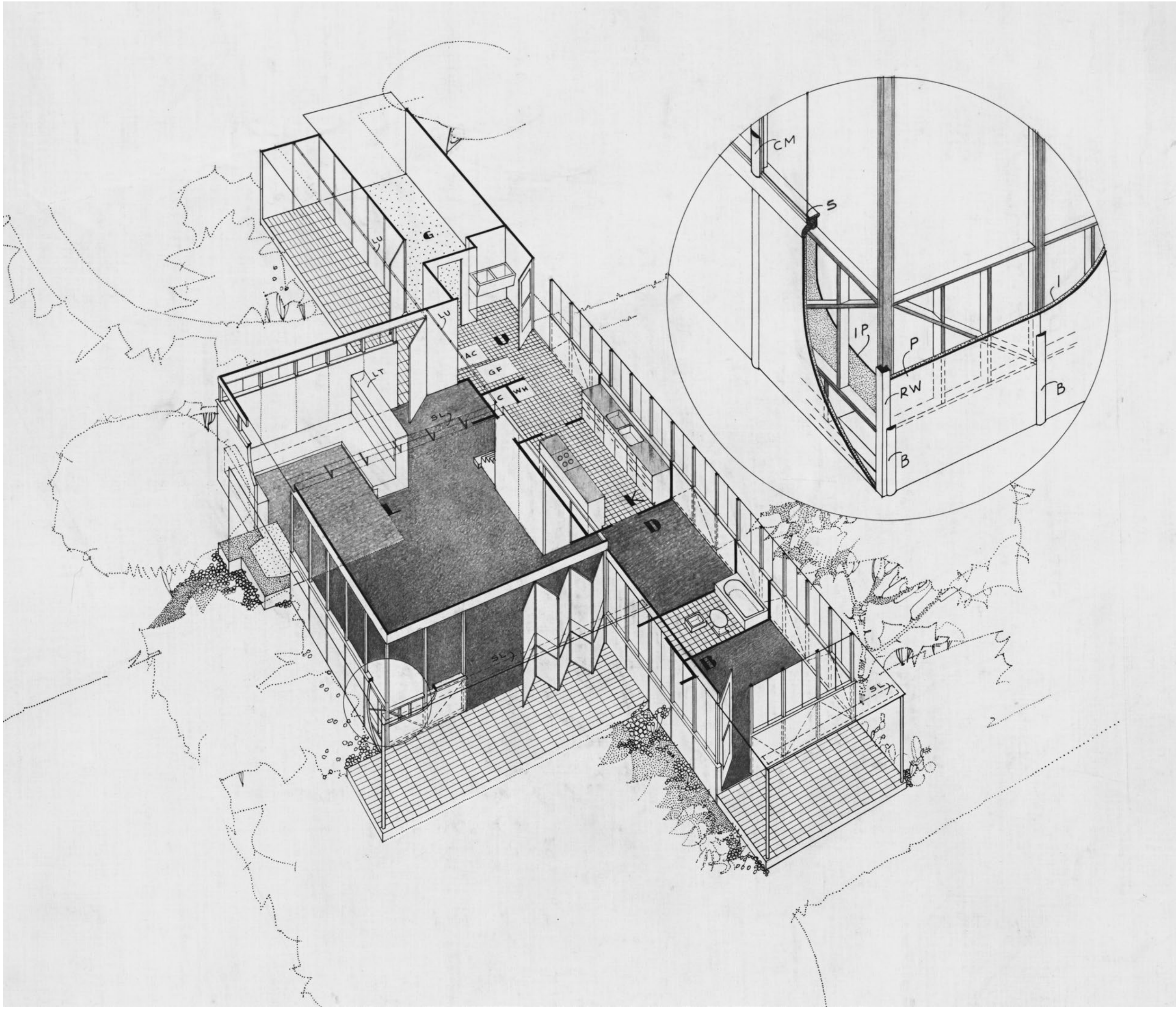

Figure 4: Original drawing of *Plywood Model House*. Source: UCLA Library Special Collection, Charles E. Young Research Library: Richard and Dion Neutra Papers, 1925-1970.

construction and avoid the need for detailed plans, he laid down a standard working system, which he resorted to appropriately, adapting details he had previously used in other projects, achieving proven optimal solutions. In this way he simplified not only the building work, but also the design process. The projects became a succession of correctly catalogued and classified details which complemented the plans. They achieved an architecture that was the sum of different compatible and adaptable building systems in which the construction process could be visualized in the project phase.

2.5. Chauffeur's House: Flexible tuning.

Friederich Fröbel was a German pedagogue known for his leading role in children pedagogy. The influence of his theories and on relevant artists and architects such as Paul Klee, Wassily Kandinsky, Buckminster Fuller, Le Corbusier or Frank Lloyd Wright is well-known. For example, Frank Lloyd Wright from the beginning used a grid that served as a reference in which to fit the building. The architect of the *Prairie Houses* exerted an enormous influence on subsequent generations of, mainly European, architects. In Holland, for example, these influenced, unquestionably, some architects of the generation after Berlage, such as Robert van't Hoff (29), J.J. Oud od Gerrith Th. Rietveld, is unquestionable. All of them related, to a greater or lesser extent, with De Stijl in which space played a leading role.

Gerrit Th. Rietveld also showed, since his beginnings as a cabinet-maker, a positive attitude toward the influence of mechanization. One of the first consequences to this was the purification in the forms of the components that he used in his furniture. It can be seen in the so-called *1908 chair* and in the well-known *Red-Blue chair* (30).

The way of projecting, which was carried out until that moment only in the production of pieces of furniture, was transferred by Rietveld to three-dimensional construction of grater scale thanks to the *Schröder House*. And, in 1927, for the first time, Rietveld used prefabricated components for the construction of a house, the *Chauffer's House* in Utrecht. These provided a delimitation of space without enclosing it, allowing it to flow between them.

This project, the accommodation for the driver on the garage as part of a larger intervention in which Rietveld had been commissioned to reform and expand the house of H. van de Vuuerts, was conceived as an experiment on the application of industrialization in housing construction. It was a parallelepiped construction in which, on one of the sides, as well as on the roof, a portion of its volume was projected towards the outside, thus breaking the delimiting planes and enhancing the idea of belonging to an unlimited outer space.

Figure 5: Exterior of the *Chauffer's House* in Utrecht. Source: Van Dijk, H. (1999). *Twentieth-Century Architecture in the Netherlands*. Rotterdam: 010 Publishers.

In Chaffeur's House the grid was used to design the plans, elevations and cross sections (fig. 05). In an attempt to achieve a versatile space with different possible distributions (31), he only used ready-made components that could easily be moved around. Without forgetting the spatial component as the major feature of this designs, influenced by the growing trend of industrialization, the constructional component was given a major role.

Using the grid as a pattern (32) and tuning the space established an initial system of relationships that structured the space and organized the distribution of the different environments, i.e. they determined all the possible positions to place the different constructional elements. The constant use of modules in the same way and in all directions facilitated the use of prefabricated components of known dimensions and shapes. This procedure, far from producing monotonous and repetitive buildings, together with the use of sliding doors and walls, meant that they could be enormously flexible with modifiable and adjustable distributions since the components could be disassembled.

2.6. General Motors in Suïsse. Rigorous gearing.

In the 18th century, the '*decorative architectur*' and the '*constructive architecture*', whose specialist of the latter was the new nascent figure of the engineer, had completely disassociated themselves from each other. An obvious example of the division between art and science was what happened in the Tour built by Eiffel. Its imminent construction and conception based on scientific notions generated a great controversy among French artists. The objectivity, typical in the application of scientific criteria, characterized the way of engineer's proceeded which differed in an ostensible way from the architect's doing. For engineers, function dictated the resulting form, beauty becoming a consequence of it. A functional form derived from the conditions imposed by material and construction and from the application of rational foundations.

Figure 6: Interior of General Motors factory assembly. Source: GTA Archives / ETH Zurich, Haefeli Moser Steiger.

Without the need for overlapping decorative elements, these constructions were able to reflect a rational beauty away from preconceived aesthetic rules.

This way of engineering proceeding exerted a powerful influence on the architects of the *Neue Sachlichkeit*, whose main defenders were in Germany, Switzerland and Holland. And in this context was born the *ABC-Beiträge zum Bauen* magazine in whose foundation participated Mart Stam, Hans Schmidt, El Lissitzky and Emil Roth, architects related to functionalism and *Sachlichkeit*. In this publication, for instance, some published articles analyze architectural projects from a more scientific point of view, such as construction methods, economy or hygiene. These architects began to substitute the arbitrary subjectivity of individuals tastes for a rigorous and objective way of doing things at the service of society and far from formal stylistics (33).

Rudolf Steiger, architect born in Zürich in 1900, also belonged to this group of architects who advocated a useful, rational, functional, accurate and scientific architecture. He designed in 1935, together with the engineer Carl Hubacher, an automobile assembly factory for the European subsidiary of the American company *General Motors*.

From the beginning, Rudolf Steiger and Carl Hubacher collaborated with the engineers of the automotive company. And from the first projection step, needs and requirements derived from function were considered. This was a new form of project collaboration where, as Albert Kahn did with the Ford Company, it was "necessary a cohesion between the work of the engineers of the production, occupied in the technical definition of the product, the lines of development and production machines, and that of the designers to whom the definition of the physical space has been entrusted" (34).

The due formed by Rudolf Steiger and Carl Hubacher opted to design the new car assembly plant (fig.06) as a complex with a spacious main building, lots of natural light and constant ventilation to provide a space worthy of the workers who had to carry out the monotonous activities of an assembly line (35). Leaving all aesthetic considerations to one side, the load-bearing structure was exposed with no unnecessary cladding along with the multiple, carefully designed structural elements with had their profiles reduced to the minimum cross-sectional areas needed in order to support the loads. The elevation of the constructed volume was designed allowing natural lighting and an appropriated acoustics environment to the tasks carried out in its interior. Different types of transit, whether vehicles, materials or people, determined the positions of the different activities and the organization of the bays to rationalize the routes. Economy and functional efficiency of the whole were the initial premises that gave rise to the perfect combination of the different components.

Architecture is identified with construction and is understood as a science in which everything must be objective. The architectural project has become a series of facts which are the result of scientific and quantifiable parameters. In a *gearing* in that everything responds to the creation of a functional whole. Buildings that are designed rigorously and according to precise calculations, economy of means and for a precise function.

3. CONCLUSIONS

The strategies identified can be divided into two clearly different groups: the first refers to the method of producing a certain product, or creating an object, in which the project and execution phases are by necessity a single continuous process, i.e. an unbreakable twosome that includes the first three strategies: reproduction, linking and manufacture. These modes of action generate architectural types from mass-produced components that are almost impossible to combine with others that have not been specially designed for the project. The design tools these strategies use are the 3-D creations of their ideas, which aids are detecting errors at the design stages.

By *reproduction* the home is considered in the project as an object whose typified form is consciously studied in order to be reproducible. Hand-made models are used to study and perfect the product's final configuration before it is mass produced in large quantities by machines. By *linking* is generated a transformable 3-dimensional structure that continuously envelops the created space. This method uses models to distribute the different components around the space and have greater control of their exact position. It makes use of previously-conceived and carefully designed elements, considering the versatility of the engendered system whose success depends on the way the pieces are joined together. By *manufacture* structures are erected whose configuration is dictated by their efficiency and materials. This strategy resorts to the used of full-scale prototypes of the actual materials to be used, since their specific characteristics will decide the final form of the product and guarantee its efficiency and good behavior.

On the other hand, strategies that use new design tools that organize the elements in different ways belong to the second group. In these, where *assembly*, *tuning* and *gearing* are included, the project phase is the most important and it is independent of the subsequent execution process. They make use of standardized components from away different suppliers, all of which are interchangeable. In other words, the organization of previously defined elements is planned by means of different project rules.

In *assembly*, buildings are obtained from a series of standard units that can be dismantled. Catalogues are used in this project strategy and the results obtained become the sum of previously tested and rehearsed construction systems and components that can be adapted to any project. In *tuning*, projects are designed with flexible and widely variable layouts that can easily be changed from one position to another according to requirements. The space is modulated to create a template in which to fit the standard elements. In *gearing*, buildings are constructed in which absolutely all components fit exactly within a categoric and harmonious whole designed for a specific function that would not be easily adaptable to any other. Scientific parameters are used in this strategy to place the elements so as to guarantee the precise operation of the building this created. The types of architecture produced by these three strategies can be identified with different degrees of prefabrication, with those designed by tuning being more adaptable and variable than those resulting from gearing, which due to being designed for a specific function are much more difficult to adapt to other ends.

The above descriptions can be summed up by saving that technological progress influenced the practice of architecture through two complementary dimensions. Firstly, as an external factor that modified process directly related to the production of defined objects, today known as closed prefabrication. The second is the internal factor that changed the way of understanding the forces that govern internally the order or organization of the elements, identified with open prefabrication. In other words, industrialization and scientific progress affected both the shape of the constructed object and the organization of its components.

Writing this research has made possible to ratify the creative possibilities inherent in materializing ideas. The manner of *reproduction*, *linking*, *manufacturing*, *assembly, tuning* and *gearing* has itself become an instrument of design with a creative novelty of first order. Six different project strategies by which architects can manipulate industrially produced materials while following diverse aims and criteria. Six different ways of approaching the interdependence of form and construction. Six different design tools that emphasize the plurality of an epoch in which the architect has stopped playing the role of conformist actor in order to take his own creative decisions, ignoring pre-established dogmas and using new linguistic codes in harmony with the times. Six different strategies with which Muche and Paulick, Wachsmann, Prouvé, Neutra, Rietveld and Steiger, each from a different standpoint, showed the way forward. The fundamental interest of these design strategies lay in the fact that they were authentic creative tools in which any pre-established formalism was rejected and the creative attitude could be extrapolated to construct a modern discourse far removed from the emphasis on aesthetics qualities restricted to space and form.

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