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Design methodology for a school prototype: Jean Prouvé's Jules Ferry School Group in Dieulouard, France, 1952–1953

The catastrophic destruction of buildings in France during World War II demanded that reconstruction become one of the primary objectives in the immediate post-war period. This favoured a culture of experimentation, and created a context for Jean Prouvé to develop designs for school buildings. He developed these designs with a research-based process focusing on technical solutions and their prototypes, and with models whose fundamental premises were rapid and easy assembly-disassembly, lightness and economy. The constant correlation between the projected object and the object created in the workshop shaped the basis for the precision of his designs. This article analyses the methodology followed by Prouvé in the Jules Ferry School Group in Dieulouard, France (1952–1953), in the singular context of the post-war period, illustrating the route followed in developing the model rather than the aesthetics of the building. The prototype used in his schools, and the models generated from this system, demonstrate his architectural methods.

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Introduction

From their inception, the works of Jean Prouvé evinced an investigatory approach that explained a way to produce and to understand architecture. Assumed as a personal commitment, he would spend all his time scrutinising and perfecting different models that were mainly devised for small scale constructions.

A considerable amount of his architectural production came from the transfer of knowledge and experiences acquired during his early years in which he worked as a blacksmith. This work allowed him to apply experience-based learning, and the material culture derived from craftsmanship, to his designs. This type of professional self-study and critical attitude with respect to the results that are obtained are identified with those values that Richard Sennet attributes to artisanal work when it is developed with the maximum personal responsibility, with collective sense and social utility: that of "doing a job well" and that of "the special human condition of being engaged."[1] These values help to understand a working method in which the planned solution is the consequence of the discovery of new problems. It is as if each test had to have an error to make an advance, strengthening that commitment which would justify the numerous designs, prototypes and variants that Prouvé realised

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throughout his life. The different modifications of his prototypes, in some cases with minimum or apparently imperceptible dimensional variations, alluded to the continuous search for perfection in which each test became a progressive *instruction* of the technique used, of the form of production, the knowledge of the material or its possibilities. Only thus would it be possible for a product to be competitive for the construction industry and thereby to reach mass production.

This open relationship in the work of Prouvé, where each solution uncovered new problems, suggests a sense of technique close to that expressed by Juan Herreros: "technique is a culture and not a collection of production systems or constructive resources."[2] This same idea of technique as a "cultural subject" is also present in the thinking of Sennet.[3]

Prouvé's designs also respond to practical questions, such as economy, lightness and rapidity, and ease of assembly and transport, characteristic of industrialised and mechanised constructions, experimental fields with a great capacity for innovation.

Against this background, Prouvé created his particular *alphabet of prototypes* to classify his work according to the prototype used: jointed frames, shell, centre core, propped and variable area grid.[4] The first three were applied in small-scale constructions. These prototypes, converted into true "lines of research," were worked on and produced by Prouvé simultaneously. In addition to recognising transfer between them, the advantage of this working methodology resided in the revision and update made in the different prototypes. This way of working responded to Prouvé's conviction that craftsmanship was viable in an increasingly industrialised world. Thus, the workshop became a productive and collaborative space, essential in his aspirational search for perfection.

With prefabrication, studied in depth and adjusted to his constructive designs and models, Prouvé attempted to provide a solution for a wide range of buildings, seeking and obtaining improved profitability and applications of his models. This required mass production, in other words, the industrialisation of his systems and their transfer to the fields of construction and architecture. However, Prouvé never managed to attain this objective: "My idea was to arrive at mass production. I always dreamed of it, but I never had the opportunity to do it."[5]

According to Prouvé, the key for a technological design to work, was to validate, in the workshop, a direct correlation between creation and execution. This method would perfect the model until the most optimal solution was obtained. Each model had to be complete, conceived and constructed as a whole, avoiding manufacture by parts and an architecture by components: "I have always been against the system of the creation of components: architecture cannot be made with components that are not coherent among themselves; architecture cannot start with a loose piece, it has never worked."[6]

Reactivating the school in post-war France

After World War II, the French construction industry was pragmatic in the face of a scenario of devastation and urgent need. The three modernisation plans that came into effect in France between 1947 and 1953, led Jean Monnet (The Monnet Plan) sought solutions for the reconstruction of the country, in which the reduction of costs and execution times had to be sufficient drivers to stimulate the new construction industry. However, on many occasions, poured reinforced concrete was used, especially in the housing sector,[7] because it is a more durable material than lightweight construction systems, which caused greater uncertainty, and were considered perishable over time. Construction in reinforced concrete also generated more jobs in all trades, helping employability in the difficult post-war years. This situation produced a greater expansion in the use of reinforced concrete, relegating the use of steel to the resolution of technical problems.

Even so, this exceptional context offered the opportunity to experiment with new technologies that drove traditional construction systems towards a systematised production of their materials and constructive units, until they were transformed into small or medium sized prefabricated elements. It was intended that these small and light elements would be put together on site, requiring a planned, rational and mechanical organisation of work, and significant manpower that was strategically beneficial in those years after World War II.[8]

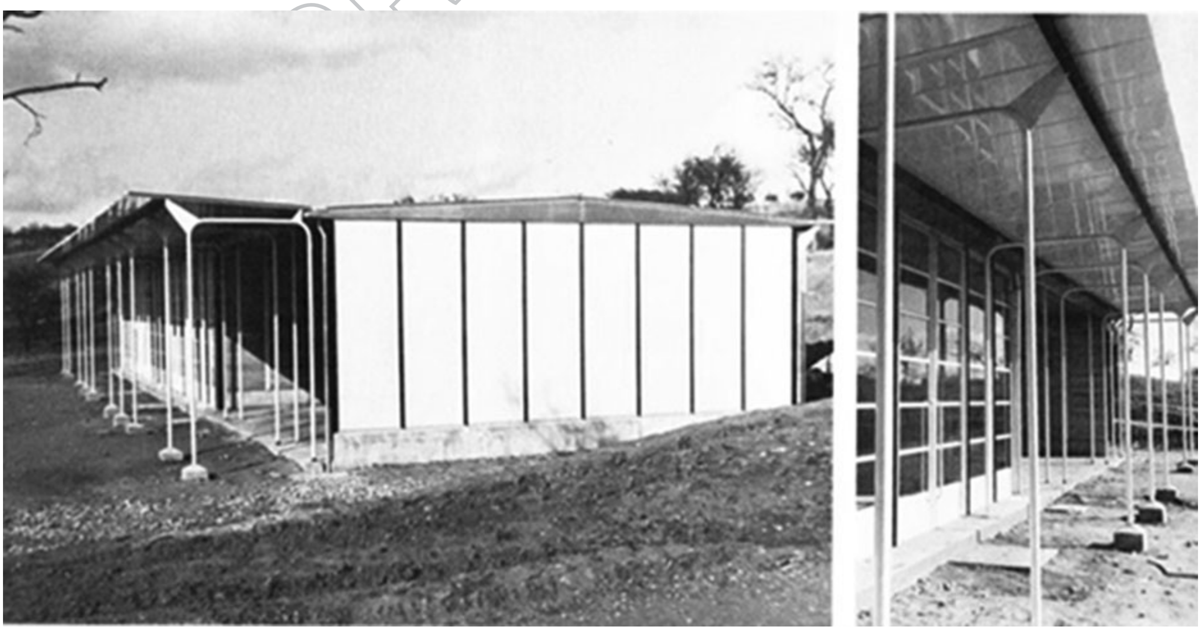
At the end of the 1940s, the French Education Ministry decided to opt for the industrialisation of construction of schools, inviting, in 1948, tenders for prototypes for school buildings. This call for tenders had the objective, among others, of establishing a strategy of collaboration between State and industry. The intent was to rectify a deficiency in school buildings through the definition of techniques, solutions and prefabricated construction systems adapted to the new pedagogical system implemented by the Government of the French Fourth Republic. The regeneration of the educational system entailed a commitment to innovation in architectural models, a belief in which successive governments participated, with the French Ministry of Education maintaining this policy until 1983.[9] The state-industry relationship, along with the need for a quick and economic type of construction, led Prouvé to become involved in this competition process.

The schools built from 1948 to the end of 1950 were part of the French state's effort to meet the needs of the municipalities. However, the municipalities were the promoters of the projects for the schools, which were subsidized by the Ministry of National Education if the project complied with the standards it had established. In the case of prototype schools, this subsidy increased. Prouvé acceded to these project conditions through competitive bidding in competition with other companies.

In November 1951, the Commission of the "Plan de l'Equipement Scolaire, Universitaire, Scientifique et Artistique" was created, directed by Senator Le Gorgeu. This Commission analysed the situation of school buildings and their requirements, producing the first map of school, university, scientific and artistic resources, for the period 1952–56. Its report evaluated the first measures and responses needed for emergency school construction, specifically aimed at primary education, due to population increase and the extension of the minimum school age in obligatory education in 1950.[10] For these reasons, demand was also growing in the other levels of education. To carry it out, the commission contacted more than 40 companies capable of producing standardised constructions, including Les Ateliers Jean Prouvé.

The results of the first pilot experience, derived from the 1948 competition, in which the proposal of the tender had been the design of a rural school, a classroom and its annexes,[11] were contemporary with the publication in 1951 of *Écoles prototypes (du premier degrè),* which included six prototypes based especially on modular systems and mass-production and in which, nevertheless, the doubts that still arose regarding the application of prefabrication and mass-production of primary school buildings could be recognised. However, in that same year, the Ministry of Education already had another eighteen tenders based on prefabricated prototypes,[12] among them the school in Vantoux, in Moselle, by Prouvé, realised in 1950 (Fig. 1). Based on a jointed frames prototype, this model had already been tested in the construction of the school group in Bouqueval in the same year (Fig. 2). The public administration gave continuity to this policy with a call for tenders in 1953 for the approval of new prototypes for primary schools of one, two and three classrooms: a national call to all the architects and companies that could construct them in any municipality no matter how small.[13]

Figure 1.
Vantoux School in Moselle, 1950. (H. Benedikt, *Jean Prouvé: Une architecture par l'industrie* (Zurich, Les editions d'Architecture Artemis, 1971), p. 138).



In order to obtain the optimal designs that allowed a reduction in costs and minimum implementation times, in 1952, the Architecture Directorate of the School Constructions Technical Services of the Ministry decided that the plans of the school models had to fit a grid of 1.75 metres, considering that this would facilitate the superimposition of different functional programmes which would compose the school complex: classrooms, kitchens, dormitories, etc.[14] This dimensional premise which related parts to whole also attempted to eliminate useless or poorly dimensioned spaces, favouring a balance in the composition of the building as well as the much desired normalisation and industrialisation of the construction. The reasons why that dimension was chosen are not clear. It neither easily facilitates subdivisions nor follows the proportions of 1.25 or 1.05 metres that corresponded to the dimensions of commercially available panels.[15] The surface area of the classroom was also examined, fixed, in 1949, at 60 square metres. There was an attempt to reduce it to 53, with the main objective being the lowering of costs, although, on fixing the dimension of the grid base to 1.75 metres, 4 × 5 modules (61.25 square metres) were needed to fulfil the minimum surface area if the modular theme were not to be broken, which would possibly entail special solutions and thereby increased costs. A problem to be solved would be how to achieve the span of 7.00 metres (4 modules of 1.75 metres) without intermediate supports, a span considered more appropriate for reinforced concrete than for light constructions of iron or wood.

Prouvé, who was against the creation of the building by independent components or elements, was also against the construction of the building being under the control of the company that sold the products. This would place economic interests above those of the social, educational and progressive objectives that architecture and, especially, school constructions should have.[16] In this

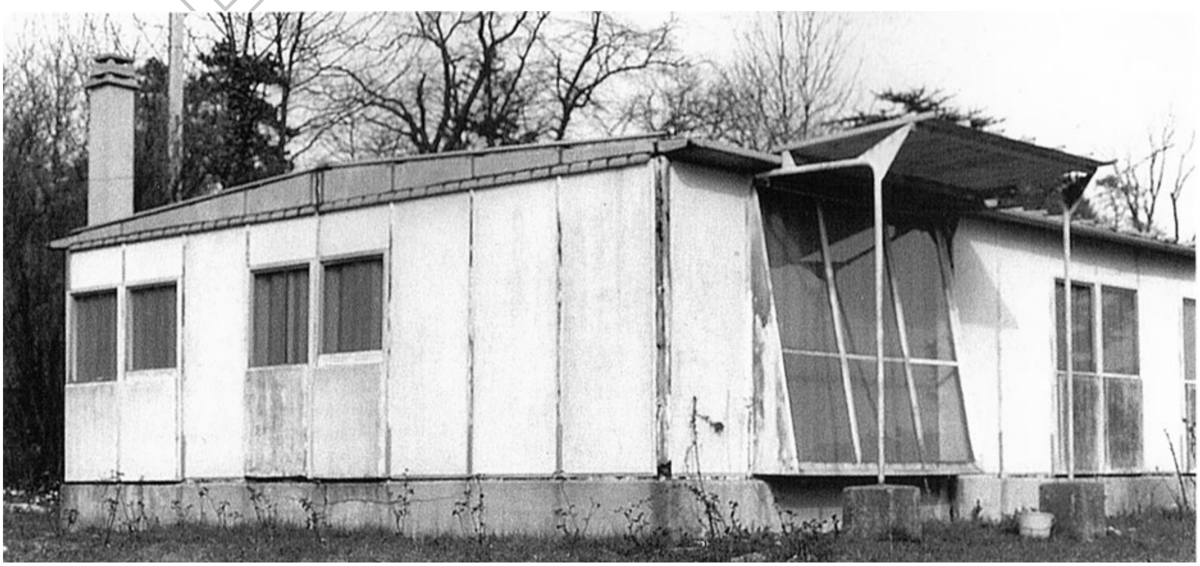


Figure 2.
School complex in Bouqueval, 1950. (P. Sulzer, *Jean Prouvé: Oeuvre Complète 3, 1944–1954* (Basel, Birkhäuser, 2005a.), p. 105).

sense, the different plans for the normalisation and standardisation of school buildings carried out in the fifties seemed to pay too much attention to commercial viability, justified by a situation of extreme necessity and urgency. Thus, when the reduction of the surface area of the classroom from 60 to 53 square metres was considered, Prouvé alleged that children, unlike surface areas, do not shrink, defending the ratio of 1.50 square metres per child as ideal for a total classroom capacity of 40 students.

Against this background, the prototypes devised by Prouvé were of a size and with some features that, through their domestic scale, presented the great advantage of being relatively easily adapted to school buildings. For his schools, Prouvé initially used a jointed frames prototype, with which he constructed or designed eight schools, between 1949 and 1951, among them Vantoux.[17] This prototype eliminates perimeter pillars, with the central supports remaining. The enclosure panels are self-supporting, thus generating a completely stable structure that allows the reduction of the number of interior supports, although the types of openings to the exterior were limited due to the supporting function of the facade panels.

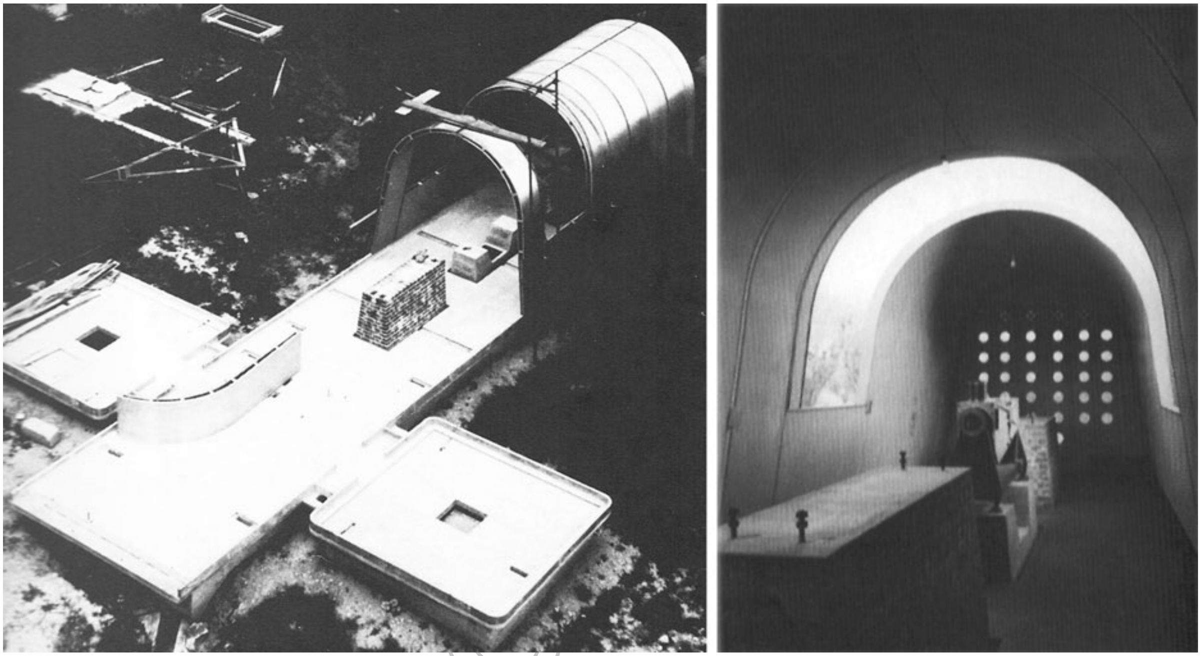
However, the most used prototype was the shell which consisted of a single element that avoided the union between roof and enclosure thanks to the continuity of its curvature. The primary objective of this prototype was to achieve a system that used the minimum number of pieces and simplified joints to reduce the margin of error in assembly. With this system, Prouvé developed a total of 40 projects and constructions between 1950 and 1954,[18] coinciding with the period in which the workshop of Les Ateliers Jean Prouvé at Maxéville (1947–56), was the site of intense activity.[19] In this studio, there was also a direct link between the sketch and the manufactured result, which Prouvé considered fundamental in order to achieve the most optimal solution. The school in Villejuif (1956–57) would be the only one constructed with a prop/crutch prototype. This model could be considered as an evolution of the shell prototype. In both prototypes, interior supports and enclosures are clearly distinguished, generating the building linearly from its cross section. Prouvé did not explore other ways of combining the cross section, nor did he propose other school typologies as alternatives to the one imposed by the literal classroom-corridor relationship.

It seems that the standards demanded by the Ministry of Education, together with the analyses and studies derived from the typical systems designed by Prouvé, created a combination of factors that justified the greater use of the shell prototype in his school proposals.

The Jules Ferry School Group

Prior tests

Prouvé had tried the shell prototype in other types of buildings, such as the Meridian Room of the Paris Observatory (1948–1951)[20] (Fig. 3). Considering the origin of the prototype, its section in the shape of a barrel vault gave rise to an approximate module of 90 cm. The domed shape conditions the functional



organisation of the building and, both the divisions and any structure necessary to support intermediate slabs, are independent of the outer envelope. The interior space is continuous and can be recognised in its entirety.[21] Other subsequent trials altered this initial design, for example, the 1:1 scale model erected in front of Prouvé's studio in Maxéville (1952) (Fig. 4). Made with metallic materials, it is similar to the systems that would later be used in the infant schools of Ferrière in Martigues (1950–53) and Placieux in Villers-les-Nancy (1951) (Figs. 5 and 6). The system would begin to be outlined, from the first designs, with a barrel vault structure that formed a continuous envelope, to more complex designs that would allow the different parts of the school to be spatially and constructively identified.

Figure 3.
Meridian Room of the Paris Observatory, 1948–1951.
(H. Benedikt and J.C. Steineger, *Jean Prouvé: Une Architecture Par L'Industrie* (Zurich, Les editions d'Architecture Artemis, 1971), pp. 51, and O. Cinqualibre, Jean Prouvé (París, Editions du patrimoine, 2016), p. 88).

If, in the first designs of the shell prototype, the division between classroom and hallway did not fit well with the vaulted form and space that enclosed the shell, in the Ferrière School building, Prouvé chose to correct it by the addition of independent volumes. Each one, responding to the different uses and functions, sought structural relationships with the elementary principles of the "shell" prototype. It could be considered as a scalar process that, starting with a modular floor, the necessary dimensions and measures were found that enabled the structural and dividing union between the different volumes.

In the Placieux Infants School in Villers-les-Nancy, Prouvé would simplify the solution tried in the Ferrière School. In his research on the possibilities for the prototype, he designed a variant that was able to absorb the corridor space for access to the classrooms, by recovering part of the initial intentions to solve the whole school building with a unique formal gesture that controlled all its construction. As in the Ferrière School, the metallic structural system was combined with masonry walls. In addition to the stability that these walls could contribute to the structural system, and the greater sound insulation between classes, it followed the recommendations of the Commission du Plan d'Equipement Scolaire Universitaire, Scientifique et Artistique of the Commissariat General du Plan de Modernisation et d'Equipement. This was to combine prefabricated construction with traditional materials, and to reduce the cost of construction by including non-specialised companies, and labour from the locality, thereby also obtaining greater acceptance in the population of the resulting school buinding.[22] These considerations, derived from the tender of 1948 already mentioned, were also aimed at making a viable product in a strongly competitive market.

The combination of the masonry wall with industrial prefabricated elements had already been tested by Prouvé in the Maison Meudon (1950–52), and was a solution that he well through his collaboration with Le Corbusier. When he worked on the Loucher houses, Le Corbusier, at a conference in 1929, defended "the fusion of craft and industrial methods to seal the alliance with local constructors".[23] He termed the wall of brick or stone the "diplomatic wall".[24] Surely Prouvé would not have been much interested in the poetic charge that Le Corbusier attributed to this wall. However, the idea was clear, Prouvé using it to resolve the contact and the support of the house with the ground, and to clearly delimit the space, already regularised and standardised, that would be constructed with prefabricated and industrialised materials. In the case of Le Corbusier, "the inhabitable technological volume" was developed in a surface area of 7 × 7 metres. In the construction of the classroom, another space of domestic, Prouvé also sought to attain the free span of 7 metres.[25]

Prouvé would follow the guidelines formulated by the Ministry, applying them in more than 25 schools,[26] among them, the Jules Ferry school group. Built with the shell prototype, which is the system that Prouvé applied par excellence, this school group is an advance in the school models developed until then by Prouvé. There were significant changes in the design and structural performance compared to other previous tests, especially in relation to the vaulted sheet that now disappears, ceasing to function as an exoskeleton to become a system of porticos. Although this solution was already in the Ferrière school and in the original example at Placieux, in the Jules Ferry group Prouvé makes advances in how the building is organised. It ceases to be linear, and instead Prouvé opts for a clearer and simpler combination depending on the programme. This decision allows him to make a more rational and standardised use of the shell prototype, as well as a singular solution of the supports that will help the school to have a composition based on basic volumes. Constructively, Prouvé develops a school building in which everything is united, related or physically supported. This structural improvement would increase the possibilities of classroom design relative to those of the previous tests: achieving greater spans without interior supports (which did not occur, for example, with the jointed frame prototype), maintaining the flat ceiling, thereby enhancing the classroom

Figure 4.
A prototype of two shells in Maxèville, 1952. (P. Sulzer, Jean Prouvé: *Oeuvre Complète 3, 1944–1954* (Basel, Birkhäuser, 2005a.), p. 325).

acoustics. In this way the resulting space could be divided with other light elements or furniture, allowing other alternatives of use. The building could also be constructed with pieces that weighed between 60 and 80 kilograms, essential for self-assembly.

The Jules Ferry school group also presents a greater entity than the school models cited above. It occupied a strategic position in the municipality where it is located, which makes it a point of reference for its urban structure.

Its programme was very basic: nine classrooms, a gymnasium and the office of the director (Fig. 7). The classrooms are grouped in lines of four and five respectively. In the middle of these two series is the gymnasium. In addition to resolving the separation of the students by gender, the floor organisation of the Jules Ferry School Group follows the general guidelines for this type of school, which were being implemented in other European countries, especially Switzerland and England. Since the school was destined for young children, the plan was developed as a single storey, with a reduced number of classrooms, resulting in an easier adaptation of the building to the needs of accessibility, hygiene and pedagogy.[27] The positioning of the gymnasium in the centre equalised the routes for both genders, whilst offering a suitable space for other activities, meetings and gatherings, influencing the social and pedagogical content that this school model could develop. Its volume, more elevated than that of the classrooms, acquired the necessary scale to be identified as the meeting place to which the organisation of the building was subordinated, while it was recognised as a reference point of the institution in its most immediate urban surroundings. The dimensions that the school acquired, like the precedents Ferrière and Placieux, led it to be thought that its construction was economically viable. At that time, and earlier, the debate regarding whether a single storey school building was more expensive than one of several stories traversed the whole European panorama. Alfred Roth alludes to the study published in 1933 by the Zurich architect, W.M. Moser, who "examined the problem of the cost in detail. The conclusion was reached that taking into consideration the total cost of all the elements of construction, one-storey schools are no more expensive than the buildings of several stories,"[28] an assertion that nevertheless depended, to a great extent, on the constructive characteristics and extension that the school reached in each case.

Observed from the outside, the Jules Ferry Group reveals the importance that this construction must have had in Dieulouard, a town in the Meurthe-et-Moselle department in northeastern France (Fig. 8). Even nowadays, in the scattered village that is based on its irregular urban plot, the school group remains as one of the most significant buildings of the municipality.[29] In the plot delimited by the present Rue Jules Ferry and Rue du Stade, the school group attempts to introduce a certain order. The wing of five classrooms, in the most acute angle, is located next to the gymnasium and the limit of the street, and the present Rue Jules Ferry defined a limited triangular space, which solved the issue of the arrival and access of the children. The wing of four classrooms was constructed up to the edge of Rue Jules Ferry that was still free, absorbing the irregular space that was generated between both. With this arrangement, the classrooms were

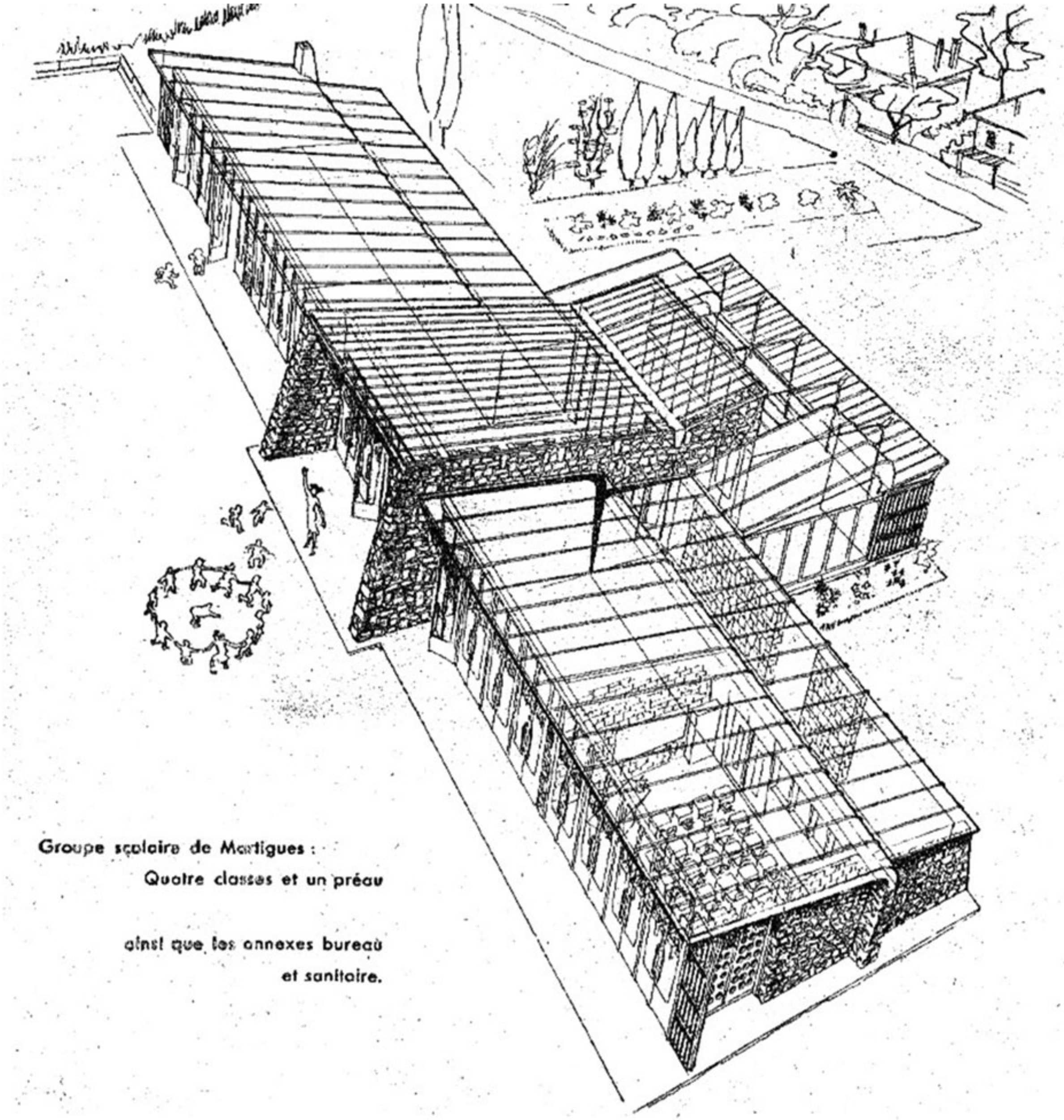


Figure 5.
Perspective of Ferrière infant school in Martigues, 1950–1953. (P. Sulzer, *Jean Prouvé: Oeuvre Complète 3, 1944–1954* (Basel, Birkhäuser, 2005a.), pp. 319).

oriented towards the southeast,[30] whereas the access corridor ran northwest. The playground was placed between the southeast facades of the classrooms and the gymnasium, and its geometry followed the orthogonal directions imposed by the school building. The rest of the plot remained free. The

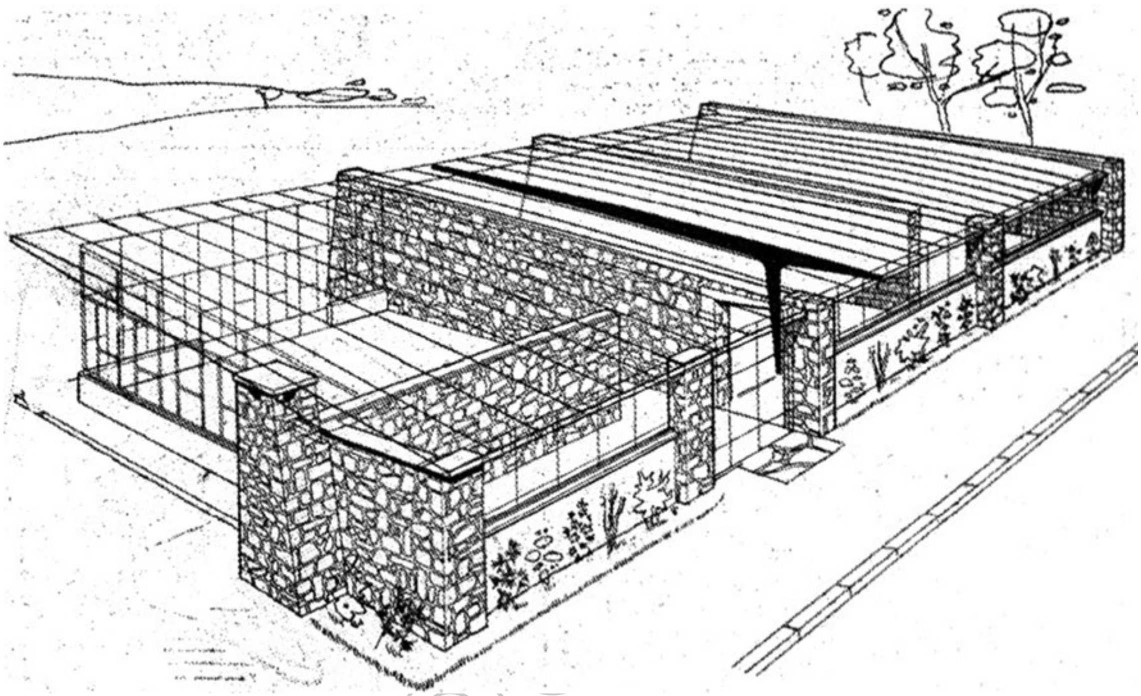


Figure 6.
Perspective of Le Placieux infant school in Villers-le-Nancy, 1951. (P. Sulzer, *Jean Prouvé: OeuvreComplète 3, 1944–1954* (Basel, Birkhäuser, 2005a.), pp. 325).

juxtapositioning of the school building and Rue Jules Ferry was an attempt to construct a clear and representative urban image. The entrance faced onto the village and the decision to position the school at the edge of the block nearest the consolidated urban nucleus seems to take into account the pedagogical principle insisted on by Heinrich Pestalozzi "the younger the child, the shorter and easier will be the way to school,"[31] something which also fitted well in the network of roads and streets into which Dieulouard was organised. On the other hand, and as Alfred Roth had advised, "the importance of physical training, games and sports was little appreciated and the open spaces and the playgrounds were generally too small,"[32] a circumstance that was resolved in this case. The outdoor space between classrooms and gymnasium, oriented to the southeast, granted the place the maximum light, air and sun in which to develop healthy activities, as the hygienist movements of the 19th century had demanded.

The construction of the classroom

Prouvé would construct the classrooms with the standard type I prototype of 1.05 metres, needing eight units per class in total (Fig. 9). Between the outer faces of the pillars and the glazing of the classroom, the recommended distance of seven metres was reached. The interior free surface area was reduced to 56.19 square metres. When Prouvé increased the width of the shell, first to 1.12, and later to 1.13 metres,[33] it was then possible to reach

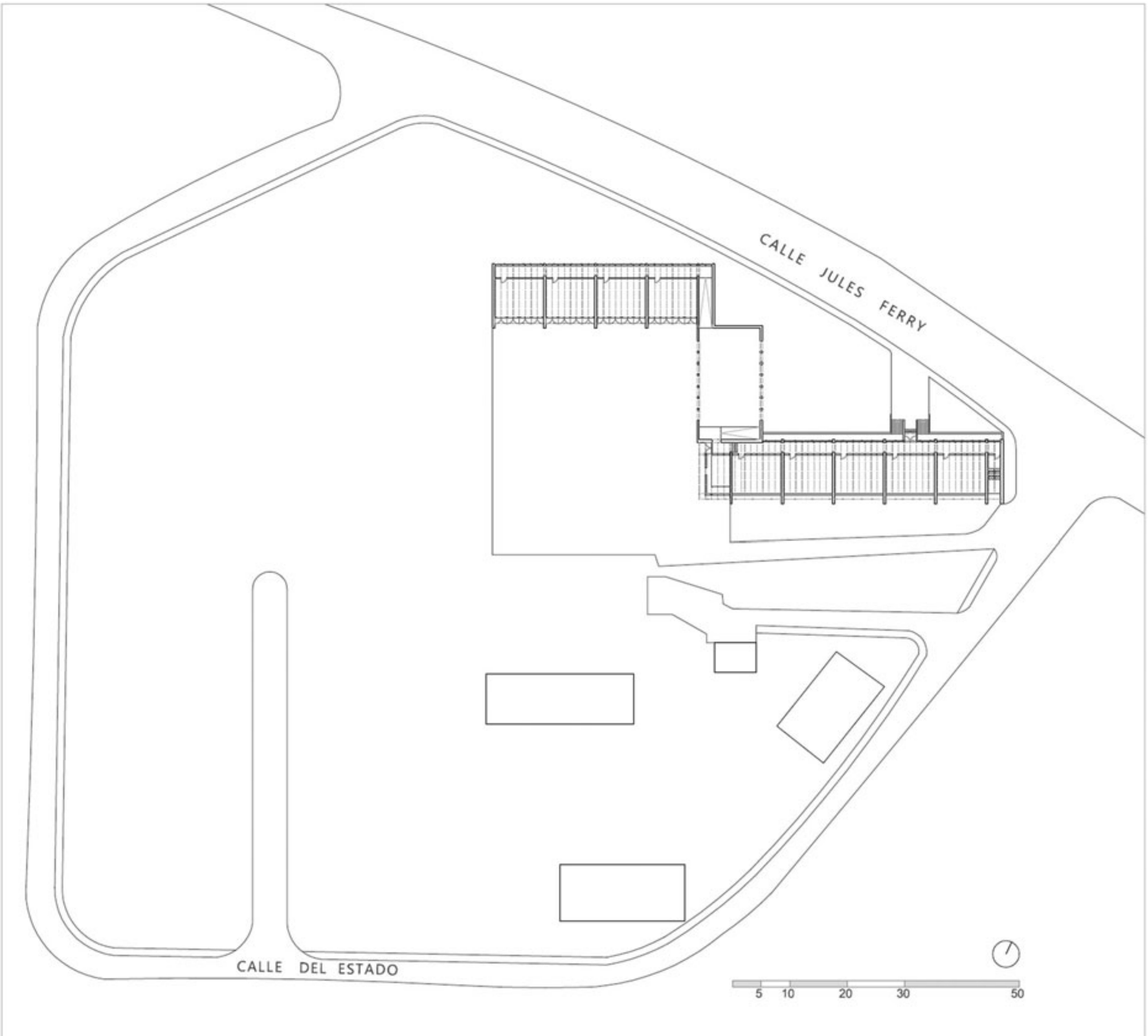


Figure 7.
Site plan of the Jules Ferry Group in Dieulouard (drawing by the authors).

60 square metres. As in the Placieux school, shells covered the corridor space that gave access to the classes. This part, as an overhang, like the cantilever that protected the glazing of the classroom, helped to optimise the resistant capacity of the shell.

The construction of the shell is relatively simple (Fig. 10). It is composed of different folded profiles. Those located on the edges are of different dimensions which allow the use of a sheet with variable sections and solve the two inclinations that the roof presents on the inside. The sheet was braced by several profiles forming a grid whose dimensions were coincident with those of the material that covers the sheet inside. On the outside, the coating was

Figure 8.
Plan of location of the Jules Ferry Group in Dieulouard (drawing by authors).

continuous to reduce the number of joints and possible leaks caused by rain. The exterior continuity of the roof sought the rapid evacuation of the water that was collected by a gutter in the northeast facade.

Duplicating the profiles on the edges of the sheet created a small air chamber inside that contributed to the thermal insulation of the roof. The structure of the sheet influences the shape of the interior support that has to be designed so that the different modules work together. As it is designed and constructed, each support is, in reality, a "frame" formed by two profiles of variable section and braced by intermediate plates. The width of the frame is the width of the sheet; the greatest demands are concentrated in the junction with the roof, with two very different spans, the classroom and the corridor, as well as enough space to join the support with the lower profiles of the sheet, justifying the largest dimension that the frame has at the top. These frames are joined to each other and form a continuous plane which, together with the masonry walls to which they are joined at their ends, completes a structural group that is stable to lateral forces (Fig. 11). With this solution, Prouvé seemed to change the 'diplomatic' condition that Le Corbusier had assigned to the wall, to that of "functional" or "structural".

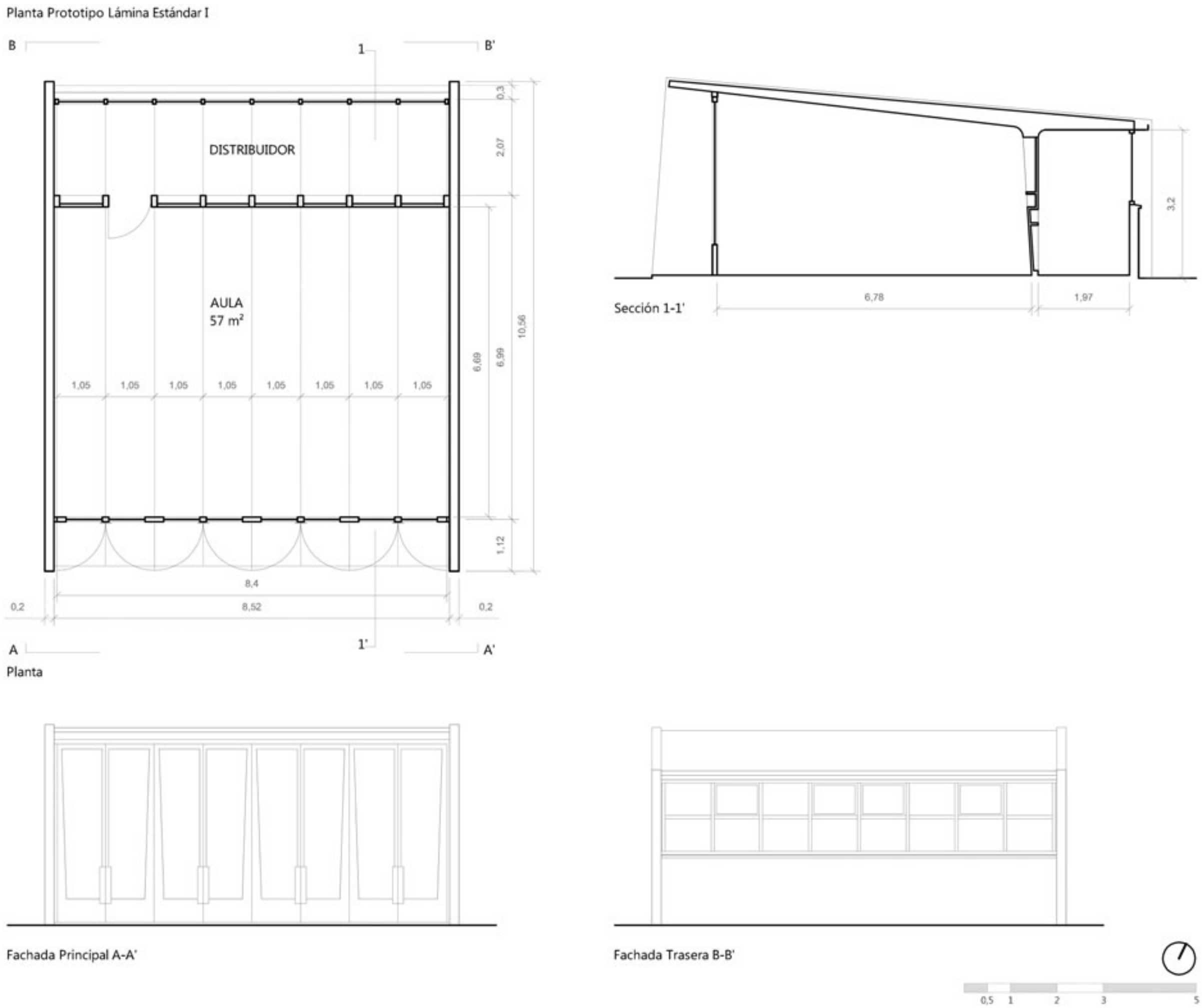


Figure 9.
Plans of Standard classroom type 1. Reinterpretation of plan 195 069 of May 1952 (drawing by authors).

The variable width of the frame would be used by Prouvé for other very different functions; using it as a shelf for storing classroom material and books, and placing hangers in the corridor so that the children could leave their coats before entering the class. This also helped to increase the necessary sound insulation between corridor and class.

An essential element in the spatial and functional configuration of the classroom was the glazing that also had to assume support functions. Some of Prouvé's designs in preceding schools introduced a beam between shell and glazing (Fig. 12), this did not avoid the joinery continuing to contribute to the support of the lamina. In these tests, the glazing was floor to ceiling and, although the frames were fixed, it allowed for folding doors. The classroom had an image similar to other contemporary examples that were designed in

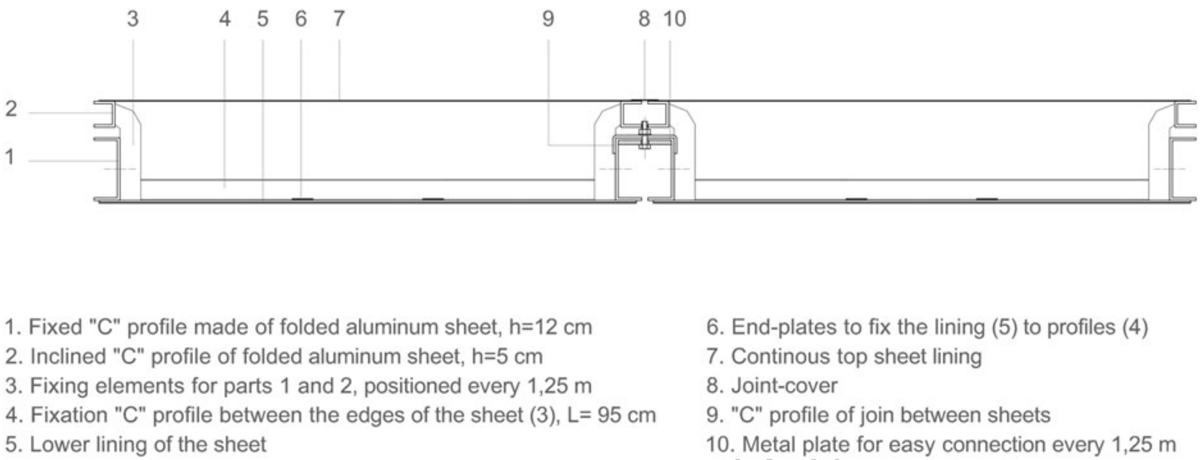
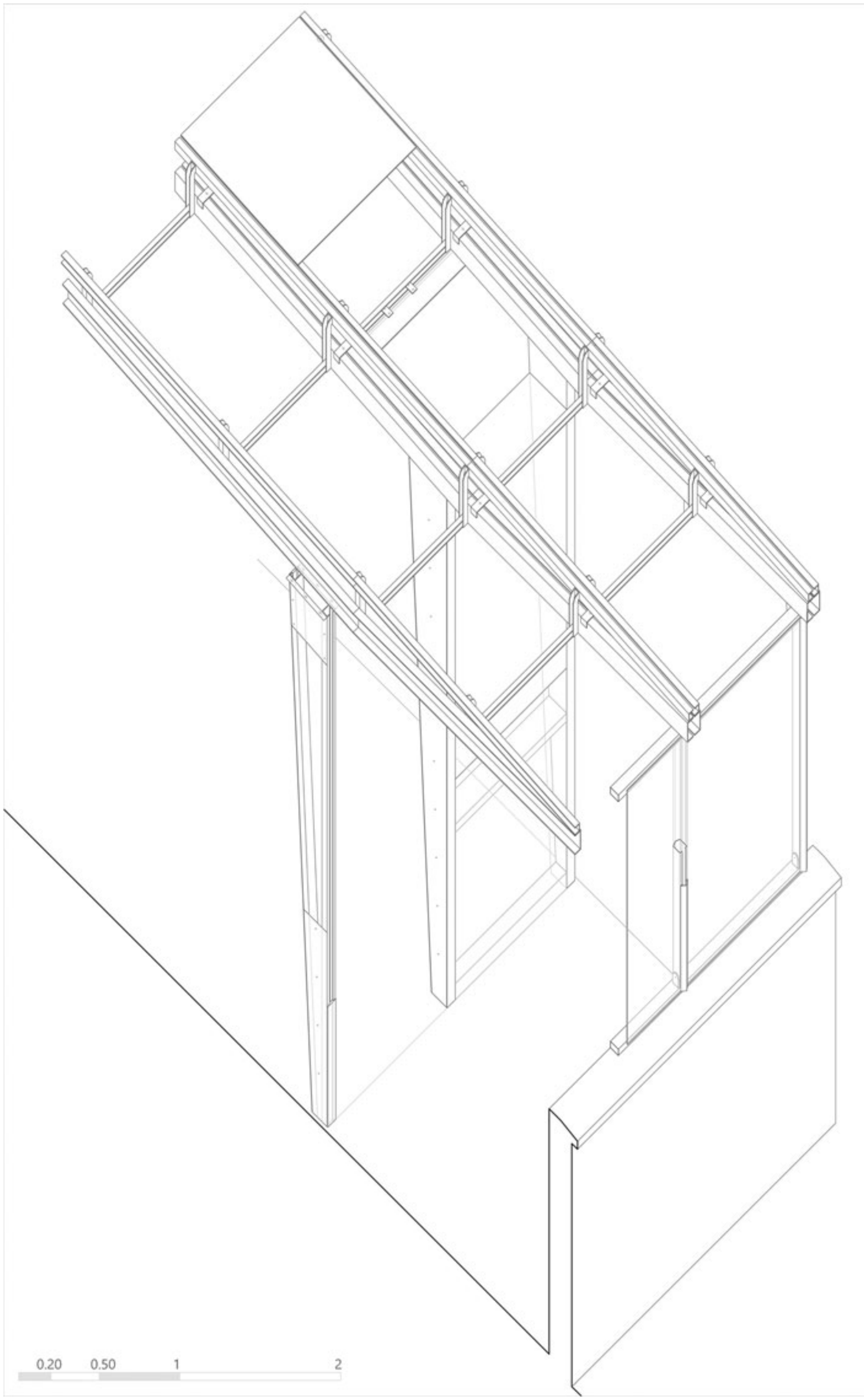


Figure 10.
Detail of joint connecting two shells (drawing by authors).

that same decade by Arne Jacobsen, or the well-known L'École de Plein-Air, constructed in Suresnes by Eugène Beaudouin and Marcel Lods (1932–35), although in this case, the frame designed by his compatriots was retractable. In the Jules Ferry School Group, Prouvé eliminated the beam between glazing and shell, entrusting all the support to the vertical mullions of the frame. He also rejected the continuity of the classroom with the exterior by introducing a low wall, thereby shortening the vertical mullions. The usable elements were reduced to operable windows inserted between fixed glass panes. The masonry walls, incorporated into the structural system of the building, allowed Prouvé a special and optimised design for the mullions. These, with a hollow and open profile that started from a 60 millimetre square section, were joined to the shell and the low wall by means of a screwed joint facilitated by a "U" shaped piece. The glass was fixed to the joinery by joint sealers, also of metal, and screwed, which also closed the open part of the mullion. Prouvé would use this solution for the large windows of the northwest facade of the access corridor to the classrooms.

The glazing oriented to the southeast attempted to achieve a uniform illumination of the classroom, and was the best solution for natural light to reach the wall opposite the glazing, the flat and slightly sloping ceiling helping to meet this objective. The overhang of 1.12 metres past the glazing attempted to protect the classrooms from the direct glare from the natural light. In cooler areas, this orientation was the most suitable from a climatic point of view: " … many years of experience demonstrate that the wings of the school must be oriented towards the southeast and not towards the south or the southwest. This way, the classrooms receive sunlight from dawn until noon, or a little earlier, and the excessive heat in summer is avoided, whereas in colder days and during the winter season, the morning sun helps to warm up the room."[34]

In the region of Lorraine, in which Dieulouard is situated, the predominant cold winds blow from the east to northeast and are mainly north-north-easterly, the warm winds come from the south and the humid air from the southwest.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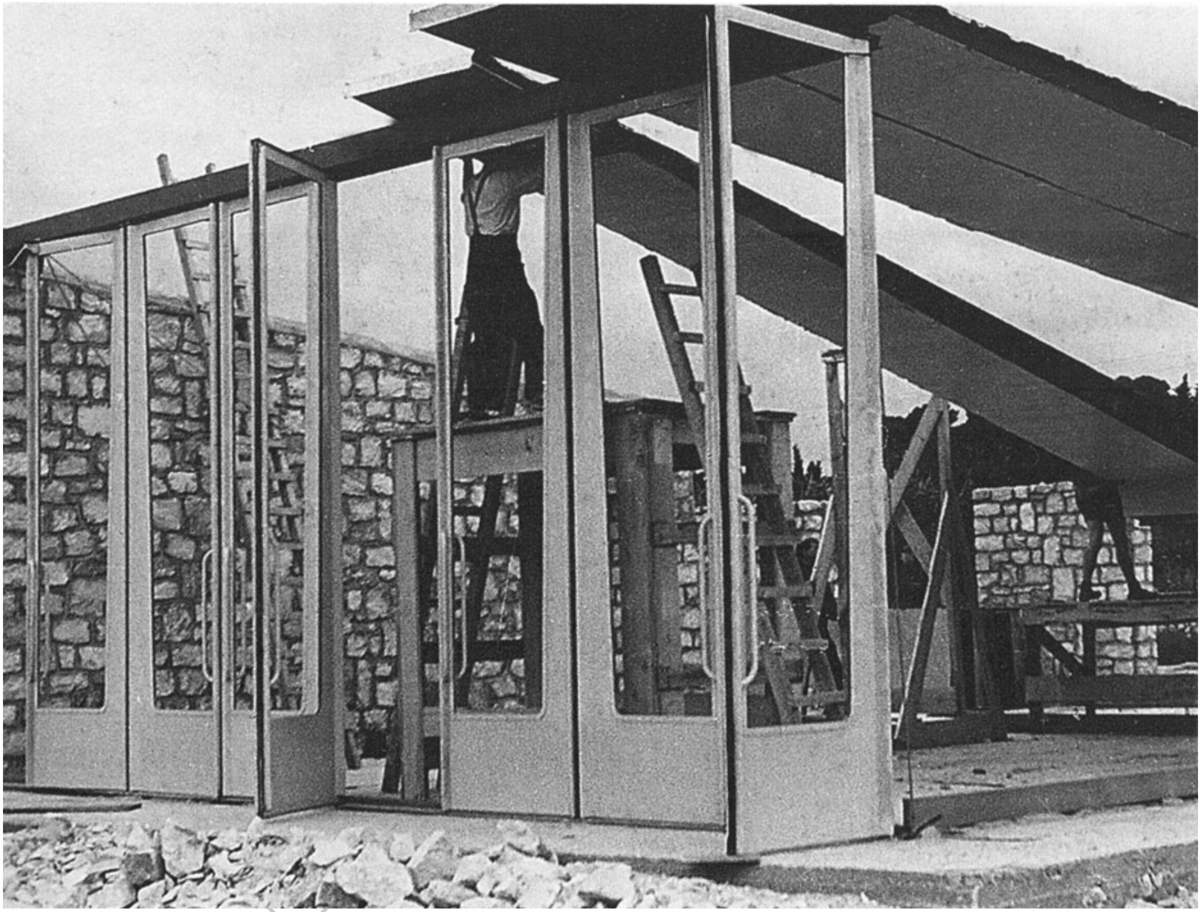

Figure 1
Constructive perspective of two shells in the Jules Ferry Group (drawing by authors).

Figure 12.
Photograph of installation of the shells of Ferrière infant school in Martigues. (P. Sulzer, *Jean Prouvé: OeuvreComplète 3, 1944–1954* (Basel, Birkhäuser, 2005a.), p. 319).

The series of classrooms were not orientated totally perpendicular to the most frequent direction of cold winds. In the absence of cross ventilation, since the upper windows between classroom and corridor did not entirely fulfil this function, the best way to ventilate the classrooms was to take advantage of the suction effects that prevailing winds would cause on the glazed facade. The turn towards the southeast also avoided the direct action of humid air, and, therefore, the most intense rain. In addition, the possible combination of humid and warm air would suppose an increase in heat, from which the classrooms were also protected.

After all the technical and functional considerations, the space of the classroom was well proportioned even to the scale of the children. The container that had defined the structural system and the glazing was finished by acquiring a certain warmth with wood cladding, both in the inner plinth which the low wall had created and on which rested the glazing mullions, and in other smaller details such as joint sealers that Prouvé placed in the union of the inner structural frames, and the shelves that constructed the bookcase-furniture that separated classroom and corridor.

Final considerations

The Jules Ferry School is a model of school building that validates the methodological foundation of Prouvé's work. In addition to the search for solutions to the regulatory and functional requirements that encouraged so much experimentation at that time, there was an investigation of the constructive form of the school model carried out with the shell prototype. The urgency of repopulation and re-education after the war served to provide a sufficient number of tests that allowed a working method to develop and a design to be investigated. It is a singular case in which, through its construction, it is possible to understand the logic of the architecture designed by Prouvé: "the advances and discoveries produced by science, engineering and industry, whose mere application would lead to a formal and generic expression of the term construction". In addition, "it is certain that in moments of necessity, the experimentation and the test, associated with determined material and constructive techniques, have served to investigate new forms, new expressions, new architecture, attempting to solve a social demand that did not find an answer with habitual means of constructing architecture."[35]

The schools that Prouvé constructed in those first years of the 1950s with the shell prototype, at the height of development and still to be perfected, revealed an attention to the functional questions of the theories and debates on pedagogy that had been taking place in Europe since the beginning of the century. Nonetheless, it seems as if the buildings that other architects constructed in response to these new educational strategies also guaranteed the suitability of the projected school models. Perhaps for this reason, but also in relation to Prouvé's type of self-taught training, he attempted to ensure that his schools were functional buildings, at least in the sense demanded by Adolf Behne in 1923, who required that the buildings were arranged on the grounds of their utility, creating "living spaces" rather than aesthetic or merely formal ones, thereby obtaining a greater and better internal unity: "the architecture would be nothing other than the permanent and visible structure of the definitive organisation of all the movements, works, purposes and destinations of a building."[36]

For this reason, there was no excessive innovation in the organisational model of the model proposed by Prouvé. The classroom-corridor type section, which defines the Jules Ferry School and its contemporaries, was already to be found in French schools of the 19th century.[37] Almost all had a corridor to the interior, and the classrooms with the facade to the street. This situation would be progressively reversed in the 20th century with the new pedagogical theories and the linking of the classroom to the playground.[38] Without a doubt, Prouvé would have known these types of schools in which he acquired part of his education.

The organisation of the Jules Ferry School into two wings with the gymnasium in the centre, is also a functional structure which has been used previously. It would be worth mentioning at least some schools by Dudok in Hilversum, such as the Bavinckschool (1921), with a "Z" layout, although in this case the classrooms (of 6 by 6 metres, oriented to the southwest and facing the playground) occupied the central part and had two floors.[39] However, Dudok was a humanist architect, with close connection to the Amsterdam School, and had very little to do with the emergent modern functionalism that Adolf Behne would later demand. The Hallgartenschule, by Ernst May and Albert Loecher in Frankfurt, constructed between 1929 and 1930, proposed four series of four square single-storied classrooms, oriented to the east. The primary school project of 1931, by the Swiss architect W.M. Moser, had two wings of one storey, with classrooms in series and an access corridor, oriented to the south and the southeast, and a third wing as a gymnasium, with the three converging in a central multipurpose space. These examples, among others, assured the suitability of the school building typology and generalised a formal scheme that would last for decades. Prouvé would apply it in his work as if it was the paradigm to follow, which responded "to the modern canon of the low height school."[40] This fragmentation of the school building in which a singular space, such as a multipurpose space or a gymnasium, would be the part that resolved the union of the wings of classrooms, connected with the trend of the 1950s which considered the school as an "open house" and understood "the school structure as an organism inserted into a living structure of greater magnitude: the district, the town, the city."[41] Dieulouard had a small population not exceeding 4,000 inhabitants and a mainly dispersed urban structure, which is why Prouvé's school was inserted on its plot with the exact intention of responding to these types of aspirations.

Prouvé's shell prototype was the modular element from which the school building arose. Contrary to an open prefabrication system, Prouvé designed his prototypes as a complete system, composed of shells and supports. It may be that this non-negotiable position was the reason why his designs never achieved the commercialisation he so longed for. It prevented elements from being combined in different ways, expanding the possibilities of application, which would have been profitable for the construction industry. Prouvé would not have shared principles like those which Gerhard Kallmann defended in 1950, which advocated an "increase of the range of design" of the different constructive components to which the architecture should respond, to allow for the growing dynamism of society, its variabilities and its future needs to be satisfied.[42] It seems that the market did lean towards construction by components or, at least, by constructive units that would allow the integration of different parts of the construction, such as the programme established by the Consortium of Local Authorities Special Program (CLASP) created in England in 1956, with which eleven schools were developed between 1957–58, and in which different constructive units could be combined in different ways. Similarly, the experience in the USA of the School Construction System Development (SCSD), established in 1961 and led by the architect Erza Ehrenkrantz, with twenty-two schools built between 1966–67. It was a system that integrated structure, facilities, lighting and mobile divisions to allow, in the same school, different distributions according to need.[43] The idea that a conditioned container could admit variability of solutions was already present in the Belair Primary School (San Angelo, Texas, 1955) designed by Caudil, Rowlett, Scott and Donald R. Goss.[44] Although it was not intended for other variants, the school, with its external enclosure of non-load bearing panels, was sheltered by a large square roof that anticipated the independence that could occur between programme, space and structure.

In Prouvé's schools, the shell, as the primary structural element from which the building and the classroom space acquired architectural form, would prevent changes in distribution, making Prouve's buildings into a type of construction that descended from the roof as the true element of reference, beneath which everything was organised. In addition, the shell was designed with a form, initially curved, and inclining in successive designs, which subsumed the building's elevation. The joinery, as a support plane, which also included the classroom access corridor, made the prototype a closed prefabricated system. Prouvé's singular design would guide the school building towards a linear model, a the solution bound up in a symmetrical transverse section, in which the corridor would become the centre-line that would give access to rows of classrooms.

Other contemporary examples showed that the classroom unit, still of only one storey, and with a skewed roof that also prevented an increase in height, was able to create an almost limitless spatial variability. It is worth mentioning the case of the Munkegård School by Arne Jacobsen (1951–58), which turned the corridors, arranging them parallel to the classrooms, to shape a plot of alternating full and empty spaces. It was an attempt to alter or to break the formal scheme that had consolidated the school models of the Thirties and later.

Prouvé's schools, however, teach the value of simplicity, the validity of a system for small scales with little dimensional variation, and how to respond to a demand with a prototype that constructed a repeatable section, while reducing the costs as demanded by governmental institutions.

The combination of different constructive systems, such as the masonry wall and the light, prefabricated elements, can today be associated with a type of hybrid technique in which natural and local materials, are combined with others more technologically advanced.[45] It would have different functions and objectives, "the first massive and energetically passive, unlike the second, slight and active. Thus arises a technological model tending towards the rationalisation of production, consumption and energy maintenance in the interests of hybrid systems conceived from a 'new environmental coherence', and tending towards a mixed aesthetic related to the contemporary world."[46]

This final reflection, jumping chronological limits, summarises one of the main objectives of architecture very well: the balance that is necessary to be reached between production, economy, technology and the environment. Prouvé reminds us that in years of uncertainty, such as those which followed the devastating Second World War, architects and an architecture tended to emerge which were capable of providing answers to future needs. Now, only time is needed for these to be recovered and, above all, assumed and understood by society.

Notes and references

1. R. Sennett, *The craftsman* (Barcelona, Anagrama Colección Argumentos, 2010), p. 32.
2. In reference to the Potteries Thinkbelt project of Cedric Price and as a critique of other architecture of a period more attentive to formal and linguistic analogies than to architecture as a construction of the real, see J. Herreros, 'Geografía, Infraestructuras y Tipos de Proyectos'. *Arquitectos Movilidad*, 190 (2011), pp. 27.
3. R. Sennett, op. cit., pp. 20, note 1.
4. On the alphabet of prototypes of Jean Prouvé, see: H. Benedikt and J.C. Steineger, *Jean Prouvé: Une Architecture Par L'Industrie* (Zurich, Les editions d'Architecture Artemis, 1971), pp. 28–74.
5. J. Prouvé. 'The architecture of the right' in A. Lavalou, ed., *Conversations with Jean Prouvé* (Barcelona, Editorial Gustavo Gili, S.A., 2005), p. 15.
6. Ibid., p. 38.
7. With heavy prefabrication, based on reinforced concrete, the Raymond Camus society built 4,000 houses, with a cost reduction of 20%, applying different productivity measures and the use of prefabrication procedures. P. Chemillier, *Industrialización de la construcción: los procesos tecnológicos y su futuro* (Barcelona, Editores Técnicos Asociados S.A., 1980), p. 361.
8. A. Resendyz-Vazquez, 'L'industralisation du bâtiment. Le cas de la prefabrication dans la construction scolaire en France (1951–1973)'. Doctoral Thesis (Conservatoire National des Arts et Métiers. Centre d'Histoire des Techniques et de l'Environnement, 2010), p. 8
9. Ibid., p. 10.
10. For the period 1952–56, 44,792 classes were needed for primary education (nursery, primary, and special needs schools) and 10,813 classes for secondary education (obligation extended from fourteen to sixteen years), Ibid., pp. 114–116.
11. The architect had freedom of choice of the constructive system and the materials to use. Ibid., p. 234.
12. Ministere de L'Education Nationale, Secretariat D'Etat Aux Beaux-Arts, Ecoles prototypes (du premier degré). Brochure du MEN (Paris, Publications du Centre National de Documentation Pédagogique, 1951), p. 46.
13. Three hundred and eighteen projects were presented, and although the results were very varied, making the objective of rationalising and regulating future school buildings difficult. It did, however, raise awareness of the need to normalise and standardise schools. Ibid., p. 142.
14. B. Vaussiére, 'Sous l'empire des trames' in A.M. Châtelet, ed., *Paris à l'ècole, "qui a eu celle idée folle … "* (Paris, Éditions du Pavillion de l'Arsenal. Picard éditeur, 1993), p. 198.
15. A. Resendyz-Vázquez, op. cit., pp. 149, note 8.
16. Prouvé accepted that "an industrialist has his financial responsibilities". The incentives of the 1950s were the waiting room of the government policy of the 1960s, based on the development of large-scale industry and, thereby, economic speculation on construction, scarce interest in innovation, the destruction of medium-sized industry and the progressive disappearance of the craftsman. J. Prouvé, 'La gran industria' in A. Lavalou, ed., op. cit., pp. 34–35, note 3.

17. The collaboration of Prouvé in the study *Ecoles volantes pour le réfugiés de la première partie de la guerre* (1939–40), directed by Le Corbusier, and which used an type of jointed frame-like structural system, is well-known. Le Corbusier, *Oeuvre complète. Volume 4.* 1938–46 (Zurich, Les éditions d'Architecture Zurich, 1986), p. 100.
18. It would be necessary to add another 16 projects made between 1953 and 1957 with a variant of the shell prototype: the studal type.
19. C. Catherine, *Jean Prouvé* (Paris, Georges Pompidou Centre, 1996), p. 30.
20. The first test of this prototype was made in the Meridian Room of the Paris Observatory, 1948–1951. The vaulted ceiling type section was constituted by two aluminium laminates joined in the upper vertex by screws. The Meridian Room has a width corresponding to the diameter of the ceiling vault, at 4.35 metres, and a length of 16.40 metres. N. Peter, *Jean Prouvé: 1901–1984: la dinámica de la creación* (Köln: Taschen 2006), p. 39.
21. V. Bueno-Pozo, *Centro de Actividades Juveniles de Ermont, Francia. Jean Prouvé. Actas del Noveno Congreso Nacional y Primer Congreso Internacional Hispanoamericano de Historia de la construcción,* vol. I (Madrid, Instituto Juan Herrera, 2015), pp. 259–268.
22. A. Resendyz-Vázquez, op. cit., p. 143, note 8.
23. A. Díaz-Segura and G. Mocholí-Ferrándiz, 'Les Maisons Loucher. La máquina para habitar se industrializa'. *Proyecto, progreso, arquitectura*, 6 (2012), p. 35.
24. Le Corbusier, *Oeuvre Complète 1910–1929* (Zurich, Les Éditions d'Architecture, Artemis, 1974), p. 199.
25. The help given by Prouvé in the design of certain prefabricated elements of the Maison Loucher is well-known, such as in the bathroom module. This module has a clear relationship with the central nucleus prototype that Prouvé would develop. Ibid., p. 43.
26. A. Leander-Pöllinger, 'Experimental school constructions by Jean Prouvé. The benefit of closed prefabrication', in Wouters, I., Voorde, S. v., Bertels, I., Espion, B., Jonge, K. D., Zastavni, D. (Eds.), *Building Knowledge, Constructing Histories*, vol. 2. (London, CRC Press, 2018), p. 1064.
27. A. Roth, *The New School* (Zurich, Girsberger Zurich, 1957), p. 36.
28. The title of the study by W.M. Moser was *Das Kind und sein Schulhaus* ("the child and its school"). Ibid.
29. The school has been recently modified, eliminating one of the wings.
30. "The sunlight cannot be so easily dispensed in more temperate zones, and many years of experience demonstrate that the wings of the school must be oriented towards the southeast and not towards the south or the southwest". Ibid., p. 58.
31. Ibid., p. 12.
32. Ibid., p. 8.
33. In 1952, he designed the type 2 standard of 1.12 metres, and between December 1952 and September 1953, the type 3 standard prototype of 1.13 metres. When Prouvé withdrew from the workshop of Maxéville, the width of the shell was extended to 1.75 metres to follow the regulatory requirements of 1949. Although Prouvé did not agree with this extension, he considered that the change of measurement was excessive and that the structural behaviour of the model would have to be reviewed. P. Sulzer, *Jean Prouvé: Oeuvre Complète. 3, 1944–1954* (Basel, Birkhäuser, 2005a), p. 302.
34. As general rule, it was thought that the square classroom worked better than the rectangular. A. Roth, op. cit., p. 58, note 25.
35. A. Ramos-Carranza, 'Construyendo formas del pensamiento'. *Proyecto, progreso, arquitectura*, 8 (2013), p. 15.
36. A. Behne, 1923. *La construcción funcional moderna* (Barcelona, Ediciones del Serbal, 1994), p. 54.

37. Some of these schools were placed in convents which were adapted to the new use, but maintaining the monastic structure of patios and galleries that favoured the organisation of the classrooms. See Chapter 4 "Primera etapa, los antecedentes del siglo XX: adaptación de conventos" in R.M. Añón-Abajas, *La arquitectura de las escuelas primarias municipales de Sevilla hasta 1937* (Seville, University of Seville. Ministry of Public Works and Transport of the Junta de Andalucía, 2005), pp. 123–152.
38. C. Weill-Rochant, 'Les Lycées affirment leur diference' in A.M, Châtelet, op. cit., pp. 90–97, note 14; P. Céleste, 'Les lycées: quand l'audace et la tradition s'afrontent' in A.M, Châtelet, op. cit., pp. 164–171, note 14.
39. Dudok constructed 28 schools in Hilversum. In many of them, the plan is organised in diverse wings, responding to a functional distribution and clear routes, delimiting spaces linked to the schools such as playgrounds. H. Van Bergeijk, *Willem Marinus Dudok Architect-stedebouwkundige 1884–1974* (Naarden, V+K Publishing, 1995), pp. 27–40.
40. F. Burgos-Ruiz, *La arquitectura del aula. Nuevas escuelas madrileñas, 1868–1968* (Madrid, Madrid Council, Arts Department, 2007), p. 78.
41. Ibid. p. 149.
42. P. De Diego-Ruiz, 'Entre tradición y transición. Génesis y cambio en la arquitectura del nuevo brutalismo'. Doctoral Thesis (Madrid, Polytechnic University of Madrid, 2015), p. 121.
43. It was requested that at least 60% of the distribution be mobile. Educational Facilities Laboratories, SCSD An Interim Report (New York, U.S. Department of Health, Education & Welfare Office of Education, 1964), p. 28.
44. A. Roth, *The New School* (Zürich, Editions Girsberger, 1975), pp. 151–152.
45. I. Ábalos and J. Herreros, 'Una nueva naturalidad (7 micromanifiestos)'. *2G*, 22 (2002), pp. 26–33.
46. J. Torres-Cueco, 'Del Tipo como teoría a lo doméstico como práctica'. *Proyecto, progreso, arquitectura*, 16 (2017), p. 45.