Geometric and Spatial Systems in Rafael Leoz

Noelia Cervero Sánchez(✉)

University of Zaragoza, Zaragoza, Spain
ncervero@unizar.es

Abstract. Rafael Leoz (1921–1976) devoted his life to the investigation of housing space and, therefore, architecture, which should lead to its harmonious systematisation, and on a later stage, to its industrialisation. He proposed studying combinatory spatial topology, which involves working with mathematical logic, and geometric and spatial systems, which come from the study of pure geometry. His space organisation systems are connected with the materialisation systems of rhythmic compositions, as he reflected in his book *Redes y ritmos espaciales [Spatial networks and rhythms]* (1969), and in his numerous articles and conferences in Europe and Latin America. In a second phase, cut short by his early death, he proposed to develop a study on the dimensions, materials and building techniques, which would lead to a new prefabrication industry. His incomplete career left us many drawings and scale models of great plastic interest that were key to develop his theory, and nowadays constitute his most valuable legacy, as they ensure its transmission and comprehension.

Keywords: Leoz · Spatial system · Geometry · Networks · Rhythms

1 Working System

Rafael Leoz (1921–1976) was, according to Moya Blanco (1978, p. 25), "a scientific researcher who could not forget that he was an architect", a scientist who rigorously sought to order abstract space, and an architect who attempted to set the space in which humans must live. He produced drawings and scale models of great plastic interest to establish his theory, as Juan Daniel Fullaondo pointed out in the journal *Nueva Forma* (1968, p. 41). This way they became an essential part of his legacy, which cannot be explained without them.

His work being internationally acknowledged, in Latin America from the Sao Paulo Biennial Expo in 1961 and praised by Le Corbusier and Jean Prouvé, who promoted his introduction in Paris in 1962 as part of the *Cercle d'Études Architecturales*, was not reflected in Spain (López Díaz 2012b). He was not able to materialise his theoretical research while alive and, after the homage exhibition held in 1978 at the Palacio Velázquez in the Retiro Park of Madrid, save some exceptions, his work was left to oblivion as abstract and limited to speculation theories (Leoz 1981).

His main objective, which was guided by his marked social awareness (Moya 1978, p. 7), was to raise the standard of science and technique for the solution of one of the

L. Agustín-Hernández et al. (Eds.): EGA 2020, SSDI 6, pp. 262–272, 2020.
https://doi.org/10.1007/978-3-030-47983-1_24

biggest problems of his time, housing. This purpose remained constant and fundamental since the start of his career at the end of the 1950s, when he took part in the policy of new towns in Madrid leading a project known as Poblado Dirigido de Orcasitas along with Joaquín Ruiz Hervás.

This first shared experience became an abstract exercise of architecture linked to the Modern Movement ideology, in its most formalist form, which, according to Justo F. Isasi in *La Quimera Moderna* (Fernández Galiano 1989, 120–121), thought like Van Doesburg that social evolution could be guided and addressed and motivated from plastic art.

At this time, Leoz became aware of the wide gap that existed between the building technique and the scientific and technological advances of engineering (Leoz 1960, pp. 705–708). He was convinced that architecture needed more efficient solutions that could be achieved from intuition and scientific systematisation. He caught a glimpse of the new theoretical principles that ranged from abandoning craftsmanship and overcoming conventional architectural practices to trusting industry as an "urgent and unavoidable" decision (Leoz 1969, p. 21).

In 1960, his consideration of the problem led him to change his professional office to create a "laboratory" investigation on "social architecture", which should achieve industrial production favouring efficiency and economy in building, starting with a theoretical study of space based on geometry and mathematics. His main aim was to fulfil general abstract space organisation principles to derive rules for ordering inhabitable architectural spaces.

Mathematics, which guided the methodologies of Le Corbusier and Mondrian in the 1920s, were once again taken up 40 years later by architects as Christopher Alexander who, in *Notes on the Synthesis of Form* (1964, p. 14), considered mathematics to be "an extremely useful tool to explore conceptual order". When the functionalism crisis occurred, Leoz proposed establishing a series of related components to formulate generating patterns of the global form, as the typical material of an extended language that adapted to the requirements of the time (Drew 1972, pp. 27–31).

The search for new patterns as a prior condition to re-establish an equilibrium took place in the 1960s by reinterpreting and acknowledging the limitations of modern architecture. In *Theory and Design in the First Machine Age* (1960), Reyner Banham went back to the sources in order to interpret mathematics as a means that the creators of the International Style used to devise a language with symbolic forms. Overcoming this artificial order by sacrificing the complexity and ambiguity of life to give way to the frankness of forms resulted in a new model, mainly in the housing and city domain, that moved further away from the CIAM's main principles. Such decadence of modernity, promoted by Team 10 and some members of the Third Generation of modern architects, was backed in Spain by a major sector of the profession.

Nevertheless, Rafael Leoz was theoretically linked to the endangered modern architecture based on the research of Gropius, Le Corbusier or Klein on functionalism in housing, as well as on the progress made by Prouvé to introduce industrial elements into social housing and architecture. Along these lines, Leoz went on to determine the fewest types of industrial components, whose use would provide the widest variety of architectural options. To develop such an open system, he believed it was necessary to consider a projective geometrical systematisation methodology for architectural spaces

(Leoz 1981, pp. 23–28). With this methodology, he sought intelligible beauty as a means to fulfil people's spatial and spiritual requirements.

2 Spatial Organisation System

Leoz's theoretical considerations started from the original form, the raw material of architecture, that is space and the way to organise it towards its industrial materialisation through complete and, at the same time, elemental "molecules". He proposed studying the structure, the only form that can be assigned to the architectural space, from the spatial combinatory analysis of mathematical logic and the architect's own artistic sensitivity. In his book *Spatial networks and rhythms* (1969), he explained this intention to overcome the exclusive arrangement of the space exclusive to each project in order to work with a constant modular system and to seek general rules, or in the words of Christopher Alexander, "to create systems that create systems".

Since ancient times, architecture has developed many processes to modulate space with regulating outlines, quite often with anthropometric intentions; in other words, by taking human proportions as measurement units. This was the case of the Greek's abstraction, which lasted up to Vitruvius and was taken up once again by Renaissance treatise writers, with independent systems based on modules that connected all parts with one another and the whole. Lecorbuserian Modulor also emerged from humankind's figure, that is from Nature, and took a "step forward" with its modular organisation on the classic regulating outlines of space by reconciling the human-proportion variables with transforming action or materialisation (Corbusier 1980; Leoz 1973, p. 11).

Although Leoz's system started from Geometry, it matched that of Le Corbusier as regards to the utmost importance of Mathematics via the proportion and numerical series that compose the Golden Ratio and the Fibonacci sequence. By taking the Modulor's blue and red series and the 0.12-m modulus as a key dimension in construction, he found similar relations to those that controlled his patterns. This enabled him to rely on a system of coordinated measurements, which he believed would provide enormous possibilities by embarking on a dialogue with a world of harmonious proportions (López Díaz 2012b). Leoz was convinced that a system with such characteristics, based on ideal theoretical conceptions and constructive conditionings, would become significant if implemented as compulsory for the whole building industry.

In his search for order backed by pure mathematics, Leoz resorted to the geometrical and faceted systematisation of mathematics as a spatial combinatory topology to organise the Cartesian three-dimensional space polyhedrically. Based on studies by Russian crystallographer E.S. Federoff, he considered four polyhedrons with central symmetry – a cube or regular hexahedron, a straight prism with a regular hexagonal base, a rhombic dodecahedron and a heptaparallelohedron or Lord Kelvin's polyhedron-, for their capacity to fill space. This allowed him to fill space without leaving gaps, to form spatial networks from their edges (Leoz 1966, pp. 1–26; Leoz 1969, pp. 61–66). These four spatial networks could endure geometrical deformations on one or several directions to create new spatial reticles.

To apply them to architecture, these spatial networks, which organised continuous space rhythmically, were decomposed by sectioning the four polyhedrons into flat networks, which Leoz divided into three kinds depending on their base polygon. A grid, of

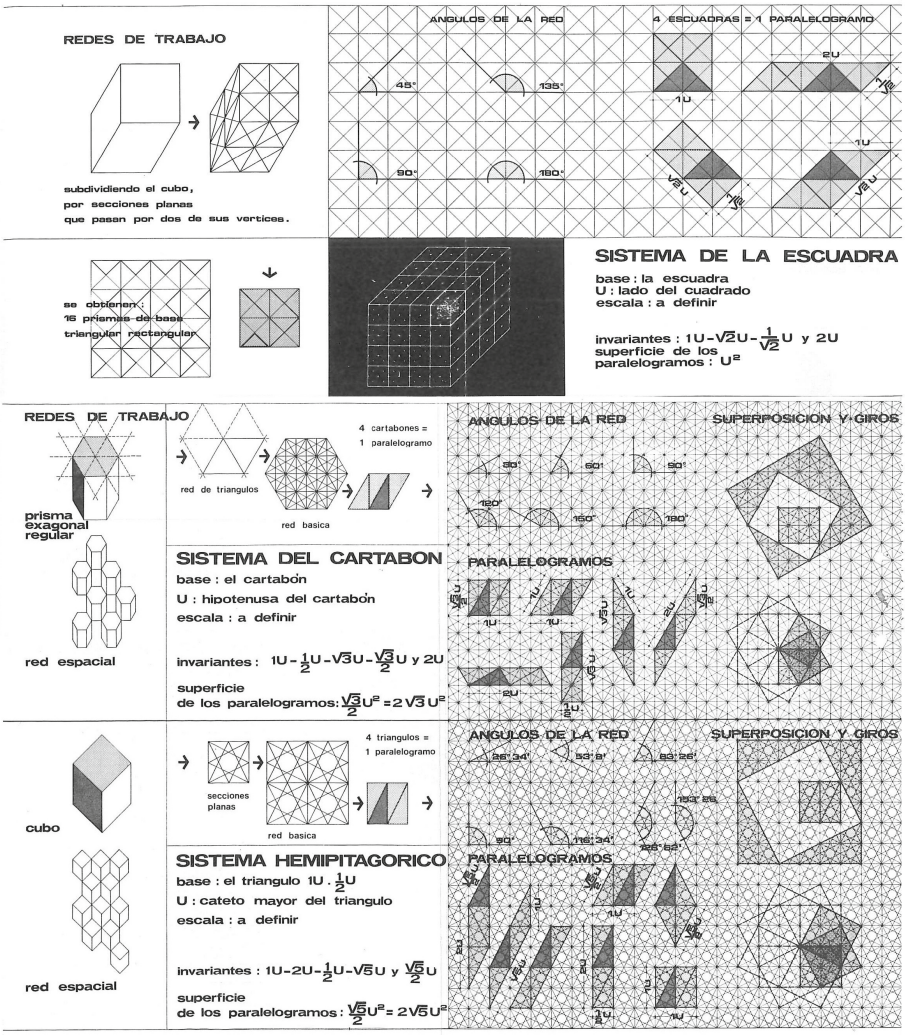

Fig. 1. Rafael Leoz. Work patterns. 1969. Source: Moya Blanco 1978.

45° set squares or right-angled triangles of equal catheti. A hexagonal network of 60° set squares or right-angled triangles with catheti forming angles of 30° and 60° with a hypotenuse and a squared double network. Hemi-pythagorean triangles or rectangles with catheti measuring one half the other, where the first and third could be superimposed on a single reticle (Fig. 1). These flat networks could stem from Lord Kelvin's polyhedron, a figure formed by six squares and eight equal hexagons in parallel to two-to-two and to seven planes or different directions. He considered all this to be extremely interesting by cross-cutting it through singular points lying in parallel to the squared faces (the reticle of the 45° set square) and to the hexagonal faces (the reticle of the 60° set square) (Leoz 1969, p. 150) (Fig. 2).

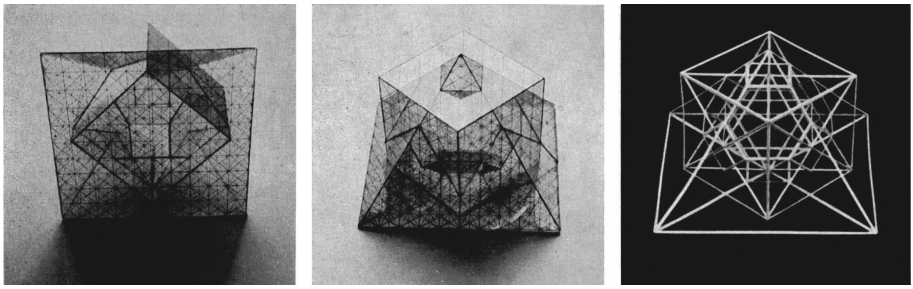

Fig. 2. Rafael Leoz. Topological complexes using Lord Kelvin's polyhedron. 1969. Source: Leoz 1969.

This methodical approach took Leoz to an architecture based on flat and spatial networks, taken as guidelines to obtain three-dimensional compositions of equivolumetric elements, to which it was necessary to add harmony and architectural sense.

3 Rhythmic Composition Materialisation System

All the infinite scales and forms used to order space that spatial networks enable comprised infinite rhythms with a numerical and combinatory capacity to overcome monotonous repetitions (Leoz 1969, pp. 94–99).

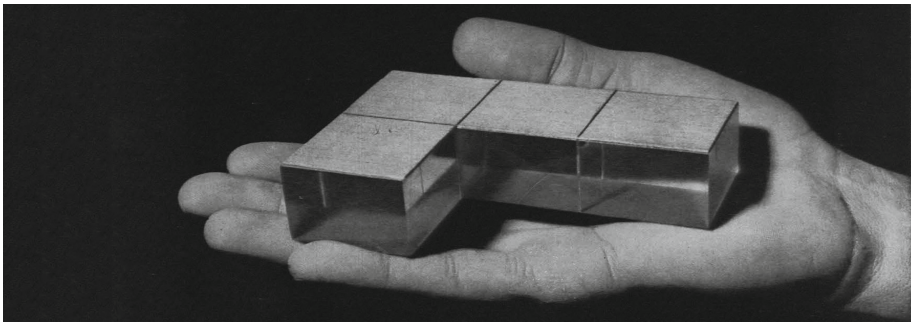

Fig. 3. Rafael Leoz. The HELE Module. 1960. Source: Leoz 1960.

The HELE Module (Fig. 3), an acrostic formed by the surnames Hervás and Leoz, was the first and simplest rhythmic composition that acted as materialised intuition in a typology of the Poblado Dirigido de Orcasitas project, which triggered all the subsequent theoretical research process (Leoz 1981, p. 43; López Díaz 2012c, p. 42). It involved a multiple asymmetric polyhedron composed of a minimum number of equal polyhedrons -three cubes in line and another at a right angle in an L-shape-whose proportions were considered beautiful as they established a connection with such a significant sequence within architecture's laws of proportion as the Fibonacci sequence (1-1-2-3). Leoz's interest lay in the maximum of combinatory possibilities that this allowed in symmetric

or asymmetric compositions, in towers or extensive arrangements, by playing or doing away with repetition, etc. (Fig. 4). Leoz also trusted in the ease of such prefabrication, being based on a single module (Leoz and Ruiz Hervás 1960, p. 41): "In any case, we believe that having such a simple basic common element with so many possibilities can be a good step towards the purpose that we all wish to achieve: obtain good architecture economically".

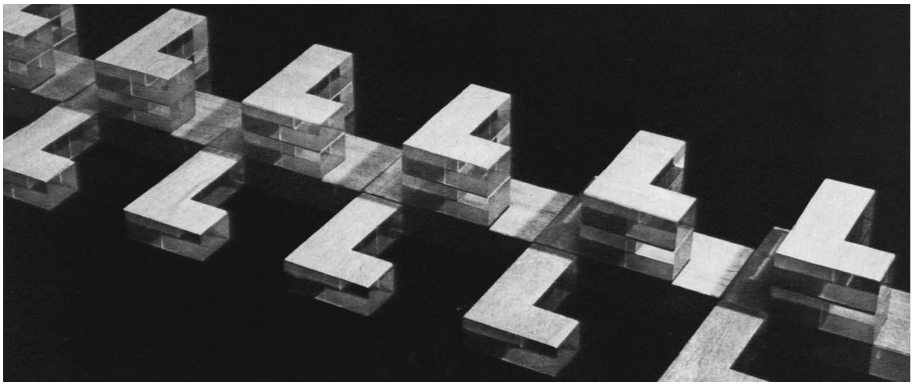

Fig. 4. Rafael Leoz. Compositions with HELE Modules. 1960. Source: Leoz 1960.

Due to its great diffusion at the beginning of the 1960s in specialised publications, and even in the press, Leoz occupied a place at the forefront of Spanish architecture's modernity. After questioning the evolution of architecture in relation to other knowledge areas in the journal *Temas de Arquitectura* (1960), he presented the HELE Module in the journal *Arquitectura* (1960), with a lengthy article whose main features were drawings and photographs of scale models showing its versatility. Despite his professional colleagues not understanding his work, which clearly came over during the conference he gave in 1962 at the Colegio Oficial de Arquitectos de Madrid [Madrid Architects' Association] (ABC, 27 April 1962, pp. 62–63; Leoz 1962, pp. 15–21). The faith Leoz had in the need for this research led him to consider the module to be a means for practicing architecture from both the conceptual and practical viewpoints (Leoz and Ruiz Hervás 1960, p. 30). "HELE, being a scale model, will be an extremely useful tool for architects in their offices… by inflexibly setting intervals between parallel lines, which is what confers it a surprisingly beautiful rhythm that we come across in nearly all the compositions made with this new module" (Fig. 5).

The polyhedral containers of human life, whose understanding and manipulation were possible thanks to scale models and drawings, render necessary for their construction an outer covering, which turned them into hyperpolyhedrons. Leoz proposed that inhabitable spaces were surrounded by other service spaces, which would reproduce or provide with a new architectural form (Fernández Ordoñez 1973, p. 205). "I have recently discovered an interesting concept: housing is a theoretically closed element with a skin; it has a skeleton, which is the structure; it has a system of arteries and veins;

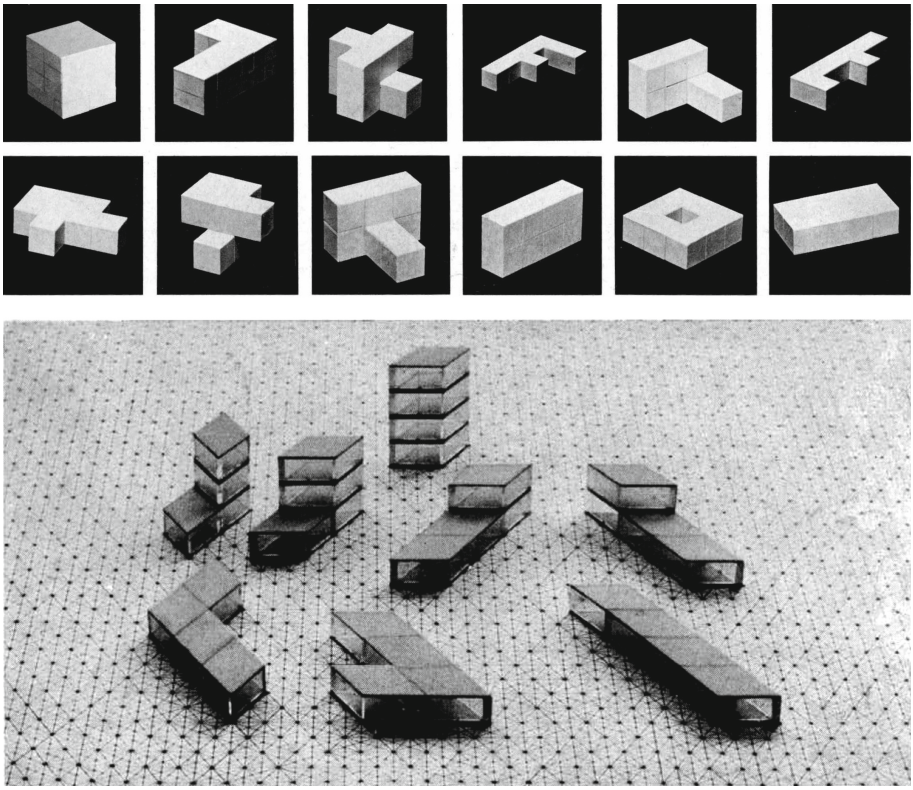

Fig. 5. Rafael Leoz. Combinatory possibilities with the HELE Module. 1969. Source: Leoz 1969.

it has an data centre and a transmission centre. So I found that the bodies, the polyhedrons, which I had handled until that time, considering them fundamental, were not what was fundamental because what was actually important were the hyperpolyhedrons formed by a polyhedron inside another polyhedron and a wrapping cover".

This figure, which Leoz obtained in his last research years, which allowed polyhedrons to be produced and related, helped to enrich his combinatory possibilities. To apply the rhythmic composition of hyperpolyhedrons to architecture, Leoz reflected on their suitability for the housing programme and was convinced that any conditioning factor could be solved by the wide range of forms he had developed, stating that his problem did not lie in creation, but in selection (Fernández Ordoñez 1973, p. 206). "What I have come across is most intriguing and starts with an almost infinite repertoire of forms. That is, if we have practically determined the form, due to the idea, for economic reasons, for social reasons, and even for aesthetic reasons, I know that it is extremely difficult to find a programme that cannot be accommodated in one of these infinite forms we have here".

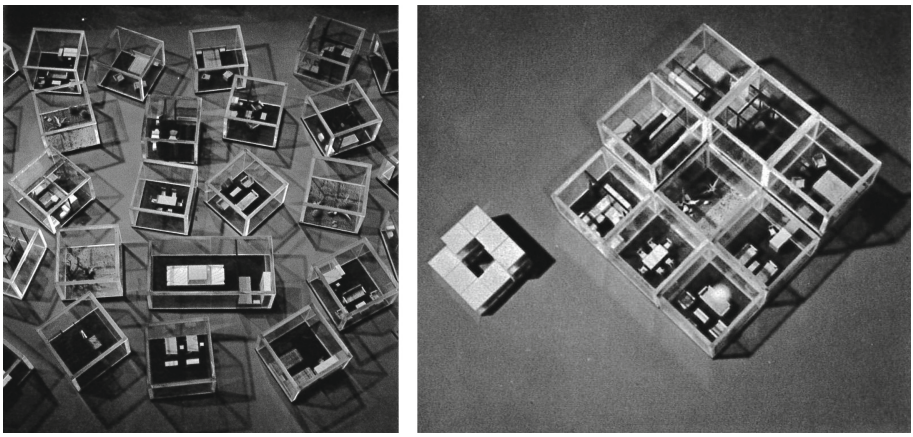

Fig. 6. Rafael Leoz. Functional units. 1969. Source: Moya 1978.

Introducing a programme in the hyperpolyhedrons allowed their material sizing to be added to the combination of modules and spatial/flat networks; in other words, the metric determination of the basic module for which he started from experimenting with the HELE Module. As mentioned in his book *Redes y ritmos espaciales [Spatial networks and rhythms]*, in 1968 Leoz started designing some housing prototypes by making a series of simplifications to the modular unit formed by grouping four straight square-based prisms, which were the equivalent to an average dwelling. He conducted sociological-type studies about domestic behaviours to establish which the most suitable functional combinations were; he defined four unit types -living, working, resting and services- and never forgot their project-based freedom and growth possibilities (Fig. 6). These groups of square-based hyperpolyhedrons varied in terms of their surface and volume until a large catalogue of floor plans was obtained.

These experiments with square-based networks or a system of 45° set-squares were also transferred to hexagonal-based networks or a system of 60° set-squares, which also provided applicable solutions and allowed analogies to be sought (López Díaz 2012a, pp. 65–66). Both research lines led Rafael Leoz to his two built works: the experimental housing at Torrejón de Ardoz (Madrid, 1973–1977), with a square-based module (Fig. 7) and the Spanish Embassy in Brazil (Brasilia, 1793–1976), with a hexagonal-based module (Fig. 8). In both cases, he applied architectural spatial systematisation by means of volumetric and highly experimented rhythms and took the first step towards modulating his structural systems.

Nonetheless, as Prouvé stated, Leoz was unable to find any industrial and financial backing to be able to put into practice his systematic industrialisation of architecture and, with it, the material construction of his theories. This last step, which would have confirmed not only the usefulness and possibilities of his geometrical developments, but would have also demonstrated their feasible application, remained a pending matter

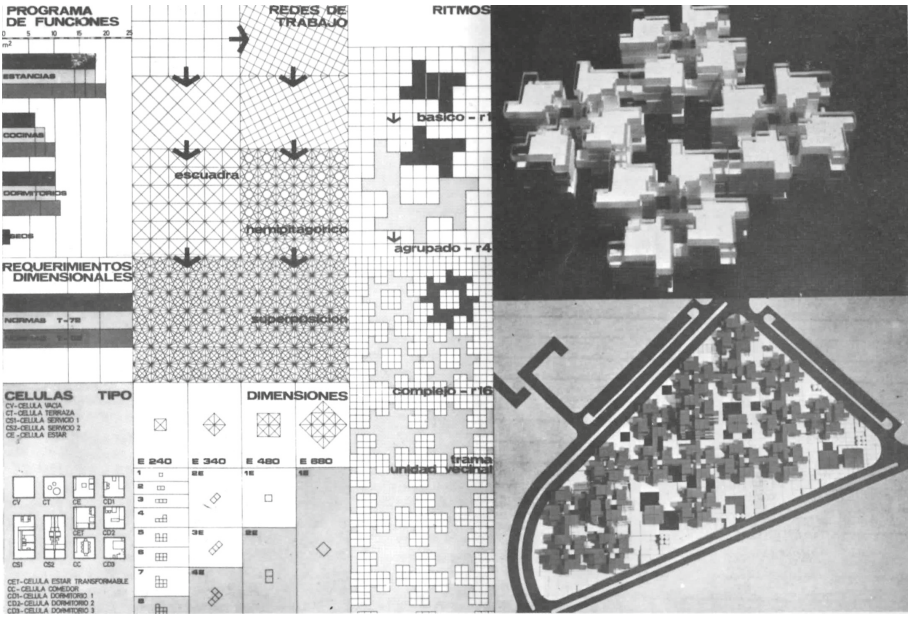

Fig. 7. Fundación Leoz. Project with a square-based module. 1969. Source: VV.AA 1978.

after his death in 1976 to be pursued years later by the Foundation named after him. His contribution to Architecture was, therefore, his theory of the harmonious systematisation of an architectural space using mathematical invariants and laws of harmony, which could not be understood without the graphical and volumetric pieces that constitute his most valuable legacy.

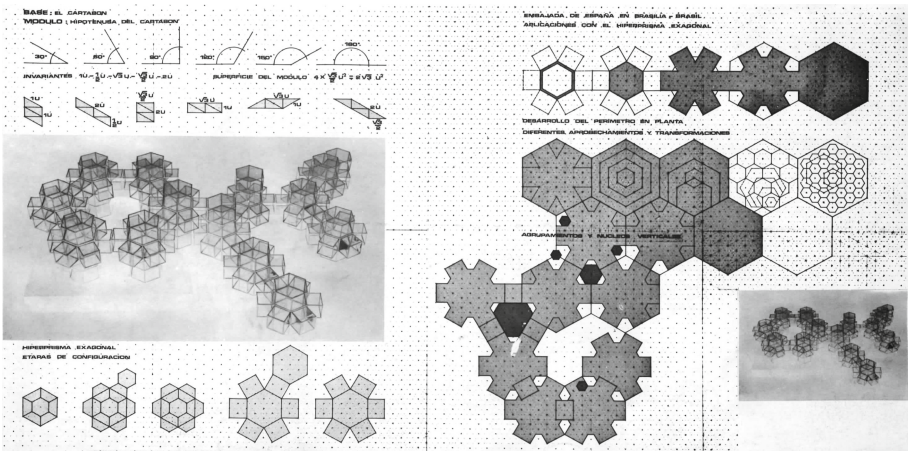

Fig. 8. Fundación Leoz. Project with a hexagonal-based module. 1969. Source: VV.AA 1978.

4 Conclusion

One constant feature of Rafael Leoz's experimental research was design and social housing production by the use of universal laws to organise architectural space. Drawing and making scale models allowed him to develop, and make visible, the systems for dividing space into volumetric rhythms capable of being industrially produced, whose combination in different ways would prevent monotony and dehumanisation in prefabricated housing.

Far from his principles falling in line with the new currents of thought, he took up again the theoretical system of Le Corbusier and the rationalist period before World War II, when what we now call Modern Movement came about, with Utopian abstract considerations and absolute trust in prefabrication systems. His theoretical consideration, far from this final production stage, originated from what is original; i.e., the raw material of Architecture: the essence of architectural space.

He benefitted from volumetric experimentation and projects on paper, which were in a very advanced stage when they were published in the book *Spatial networks and rhythms* in 1969, which based architecture on geometry. For practical and aesthetic reasons, he found in symmetry and proportion systems the conditions to outline an inhabitable space, relate it with mankind's scale, facilitate its construction and acquire harmonious beauty that was, assumedly, a reflection of ideal geometry.

Leoz was convinced that his "discoveries" about the systematisation of architectural space would be universal and revolutionary, and would start a "Renaissance of architecture" and its universal laws. The material construction of this theory proposed providing a "catalogue" with wide-ranging formal games and a fast execution by industry. As this last stage, which depended on the industry sector, is lacking, his most valuable contribution is the graphic and volumetric representation of his theories and prototypes, which have been shown in this communication.

References

Alexander, C.: Notes on the Synthesis of Form. Harvard University, Cambridge (1964)
Banham, R.: Theory and Design in the First Machine Age. The Architectural Press, London (1960)
Drew, P.: Third Generation. The Changing Meaning of Architecture. Pall Mall Press, London (1972)
Fernández Galiano, L., de Isasi, J.F., Lopera Arazola, A.: La quimera moderna. Hermann Blume, Madrid (1989)
Fernández Ordóñez, J.A.: Conversación con Rafael Leoz de la Fuente. In: Arquitectura y represión. Seminario de prefabricación, pp. 203–214. Cuadernos para el Diálogo, Madrid (1973)
Fullaondo, J.D.: Agonía, Utopía y Renacimiento. Nueva Forma **28**, 41 (1968)
Leoz, F.R.: Arquitectura e industrialización de la construcción. Fundación Rafael Leoz para la Investigación y Promoción de la Arquitectura Social, Madrid (1981)
Corbusier, L.: El Modulor. Poseidon, Barcelona (1980)
Leoz, R., Ruiz Hervás, J.: Un nuevo Módulo volumétrico. Arquitectura **15**, 20–41 (1960)
Leoz, R.: ¿Vamos por buen camino? TA: Temas de Arquitectura **18**, 705–708 (1960)
Leoz, R.: División y ordenación del espacio arquitectónico. TA: Temas de Arquitectura **39**, 15–21 (1962)
Leoz, R.: División y organización del espacio arquitectónico. Arquitectura **89**, 1–26 (1966)

Leoz, R.: Redes y ritmos espaciales. Editorial Blume, Madrid-Barcelona (1969)
Leoz, R.: Humanismo, investigación y arquitectura. Arquitectura **173**, 11–35 (1973)
López Díaz, J.: Rafael Leoz: el arquitecto y su legado. In: VV.AA., Rafael Leoz, arquitecto de la Embajada de España en Brasil, pp. 26–67. Briquet de Lemos, Brasilia (2012a)
López Díaz, J.: Tras los pasos de Le Corbusier: la modulación geométrica y la vivienda social en las teorías del arquitecto Rafael Leoz (1921–1976). In: Proceedings XVIII Congress CEHA, Santiago de Compostela, 2010, pp. 1850–1859 (2012b)
López Díaz, J.: El Módulo HELE de Rafael Leoz, una historia de contradicciones: del éxito internacional a la difícil relación con la arquitectura española, RA: Revista de Arquitectura **14**, 37–50 (2012c)
Moya Blanco, L., Leoz, R.: Ministerio de Educación y Ciencia, Madrid (1978)
Boden (coord.): Monográfico sobre la Fundación Rafael Leoz, no. 17. Boden (1978)