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Study of the validity of the constructive system LAD-MA for the self-help housing of incremental housing

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Abstract: Since the mid-1980s and until the early '90s of the twentieth century, various NGOs working on the housing problem for the most vulnerable segments of society in Chile explored different alternatives to offer practical solutions in a context of political dictatorship and a State with low response capacity. Among the NGOs of the time, «Taller Norte» Technical Assistance Center stands out. This article is part of an investigation that retrieves the technological experience of the LAD-MA construction system design, created to be used in mutual self-help programs. The study analyzes the effect that the economic and political social context of the time had over the system design, seeking to establish the validity of the construction system in the current social economic and political conditions.

Key words: construction of houses; prefabrication; social housing; mutual self-help housing

1 Introduction

This research examines the LAD-MA construction system, conceived in 1989 by the NGO Centro Urbano de Asistencia Técnica Taller Norte for the "Construyendo Juntos" assisted self-construction program for progressive housing [1], in the popular neighborhoods of Peñalolén Alto and Lo Hermida in the commune of Peñalolén in Santiago, Chile [1] [2]. Its functional, technological, and economic aspects are analyzed in accordance with Monjo's "Proposal for the Evaluation of Construction Systems" [3] to determine its current technical and social utility.

The issue of low-income housing production is as relevant today as it was in 1990 when LAD-MA homes were built. The differences lie in the fact that in 2017 the country already had a per capita income of US$21,346.4, six times higher than in 1990, when it stood at US$2,500.65 [4], and significant changes have occurred in public housing policy. In the early 1990s, Chile was just emerging from a dictatorship that had transformed the state's approach and role by implementing a neoliberal model that drastically reduced public spending and granted the market a place that the state had previously held for itself. Social housing, rather than a right, became a commodity accessible through savings and credit. [5]. Under the slogan "Chile, a country of homeowners," the military government set out to reduce the housing deficit,—which, according to Joan MacDonald, stood at 820,959 housing units in 1982 [6]—through a policy of housing subsidies aimed primarily at groups with a certain capacity to save, leaving the most marginalized segments of society outside the scope of state support.

In this context, the «Taller Norte» Urban Technical Assistance Center, an NGO, worked from 1983 to 1993 on issues related to low-income urban housing, the development of construction technologies, and mechanisms for action and participation by residents of low-income neighborhoods, helping them to take the lead in autonomously improving their living conditions and, more broadly, the processes of democratization and social change in the country during the final years of the military dictatorship.

The NGO, in collaboration with the neighborhood organization, promoted the creation of the "Construyendo Juntos" committees [7] as a socially organized way to address the housing shortages faced by families in Peñalolén Alto and Lo Hermida in the municipality of Peñalolén. This housing construction initiative was based on the integration of three fundamental principles:

1. Popular organization and management, based on the principle of mutual aid.
2. Social organization for the procurement and administration of financial resources and technical assistance, whether from the State or another institution.
3. Technological and economic innovation, based on an alternative, low-cost system that allows for the possibility of subsequent, progressive expansion of the housing units.

Based on these principles, various housing improvement and technological initiatives were developed for housing construction. Initially, work was based on a system of wooden and mud partitions. Although this solution helped resolve the housing shortage for many program participants [2,8], it did not gain widespread acceptance among neighborhood residents, as many associated it with the precarious and poor housing of their childhood in rural areas. Toward the end of the 1980s, in the waning days of the dictatorship, Taller Norte developed the LAD-MA system, a construction alternative that incorporated fired clay bricks in the walls, a material widely accepted by the community. We do not have reliable data on the total number of experimental homes built using this system, but according to estimates by one of the technicians who participated in the project, there were approximately eighteen such cases, of which only six—located on Rio Lauca Street in Peñalolén Alto—could be documented. Twenty-eight years have passed since this experiment, and we wonder whether that construction system is merely a relic of the past or remains fully or partially relevant today.

2 Methodology

The research focused on the LAD-MA construction system, its social, economic, and cultural foundations, and its technical aspects. The first part of the research consisted of reconstructing and processing the documentation available in old archives and records related to the system and the construction and organizational process carried out by Taller Norte until it ceased operations in 1993. These proposals were analyzed in light of current housing policies, programs, and regulations. Subsequently, in six of the homes built using the LAD-MA System on Rio Lauca Street in the Peñalolén district, a survey of plans and photographs of their current configuration was conducted, along with an analysis of their state of preservation and the changes they have undergone over the past 28 years. In four of the homes studied, "Netadmo" home weather stations were installed; for one year, these have been transmitting data via the Internet on temperature, humidity, noise, and CO_2 levels inside and outside the homes, the results of which are analyzed in detail in another section of the research. To date, this has allowed us to formulate new questions regarding the relationship between the observed results and the construction system, the original architectural condition of the homes and their transformations, and, particularly, the patterns of use and the methods of heating and ventilation. The assessment of the homes' state of preservation was visual, with the primary focus on the condition of the wood, as it is the element most susceptible to damage from environmental conditions and biological attacks. This was supplemented by a questionnaire administered to the families regarding: the maintenance they had performed on the walls and pillars, heating habits, and the choices they

made when expanding their homes.

To analyze the building system, we used Juan Monjo Carrió's proposal for the Evaluation of Building Systems [3], as it was considered to provide a current analytical framework appropriate to our problem. The author argues that selecting a building system requires its evaluation, weighing its architectural possibilities without reducing them to mere formal attributes. To this end, he proposes addressing three aspects ─ the functional, the formal, and the technological ─ considering a set of variables for the analysis of each. We have also adopted the aforementioned author's definition of "construction system" as a "set of materials, elements, and related construction units coordinated with one another by physical and geometric laws, with the ultimate goal of constructing a building or part of it." These aspects will allow us to control all phases of a project from design through construction.

In accordance with Monjo's definitions, we can characterize the LAD-MA system as a partial system or subsystem intended to address a specific structural component of the building, which in our case corresponds to the subsystem of load-bearing walls composed of a wooden structure with a body of brick tiles prefabricated in a workshop and foundation beams prefabricated on-site. Within this same framework of definitions, the LAD-MA corresponds to an open system insofar as it allows for the incorporation of multiple commercially available elements.

3 Background of the construction system

LAD-MA is a construction system that was conceived for use in one of the housing programs promoted by Taller Norte in the late 1980s during the military dictatorship. It originated from two variables: one of a socio-cultural nature and the other of a technical nature. The sociocultural variable refers to the deeply rooted belief among working-class communities in many regions of the country that housing is only dignified and permanent if it is made of "solid materials," a term used to denote its sturdiness. The cultural context of the user leads them to prefer "solid" housing "made of brick and concrete"─terms used to describe masonry and reinforced concrete. "The custom is to tap the walls to see if they are hollow, accepting only what is monolithic, heavy, and rigid, based on stone materials" [9]. Solid housing would also distance itself from the image of poor, rural housing made of light and perishable materials.

Furthermore, the system was designed to facilitate the participation of inexperienced users—mostly women—as labor in the construction process through mutual aid and self-construction; at that time, it was very common for women to take the initiative in addressing the family's needs. Women's work was facilitated by carrying out tasks in a workshop and on-site with the support of supervisors. The technical aspect referred to the need for an economical construction system that was easy to implement and guaranteed structural stability.

The system was designed to be implemented in stages of progressive development. The first phase was carried out by the families themselves with technical and financial support from the NGO, and the second phase involved improvements and new construction projects of varying scope, determined by the financial and material resources available to each family. [1]. The first stage consisted of a habitable shell that could be improved. These improvements mainly consisted of mortar plastering over brick panels, paints and varnishes to protect the wood and wood or drywall panels, insulation on the wooden second floor, and any extensions required by each family.

In short, the aim was to address some of the aspirations felt by the users through a low-cost, safe, and easily executable alternative, using local materials accepted and familiar to the people, and procedures that allowed for construction with user participation and progressive development.

4 System description

The LAD-MA system consists of a set of four standard wall panels (Figures 1, 2, 3, and 4) that can be arranged according to the architectural design. The load-bearing walls consist of a structural framework of 2 x 4" untreated pine

studs and top plates, braced with 1 x 4" pine diagonals, which act in concert with a body of prefabricated tiles made from "ladrillo fiscal" [2]. The brick panels are secured to the wooden structure and to each other using 400 kg/m³ cement mortar and horizontal reinforcement for shear stress consisting of 6 mm smooth round rebar, secured by bending and clamps at one end of the wall panel, and tensioned and secured at the other end with locknuts. For attachment to the foundations, an 8 mm ribbed steel bar was used at each end of the wall panel, secured at the top with clamps (Figure 1).

On-site, the foundation footings are cast directly into an excavation without forms. The foundation beams are prefabricated on-site using forms that contain guides to position the 8 mm anchor bolts at the center of the bottom flanges. The foundation beams are mounted on the foundation blocks, which are perfectly leveled on their upper surface. A wooden floor framing is laid over the LAD-MA structure to create a second floor, which is entirely constructed using a traditional wooden structure that in many cases was sourced from the recycling of the precarious housing (Figure 4).

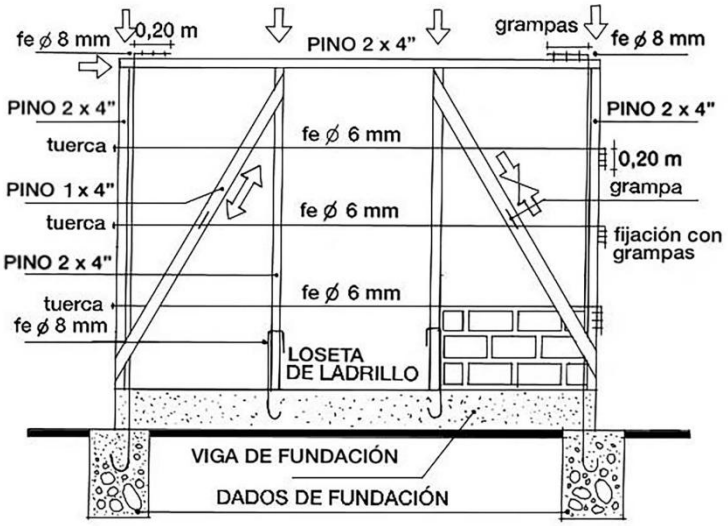


Figure 1. Diagram of an LAD-MA wall panel

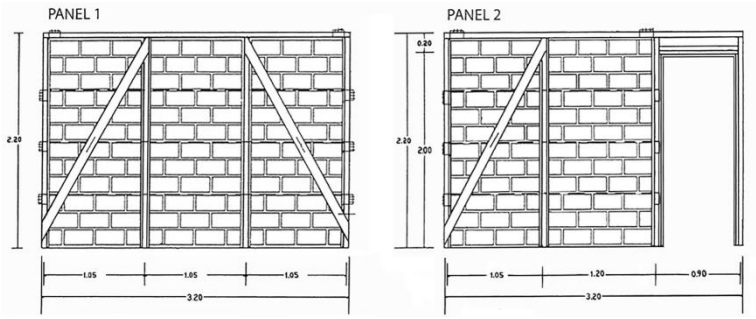


Figure 2. LAD-MA wall panels 1 and 2

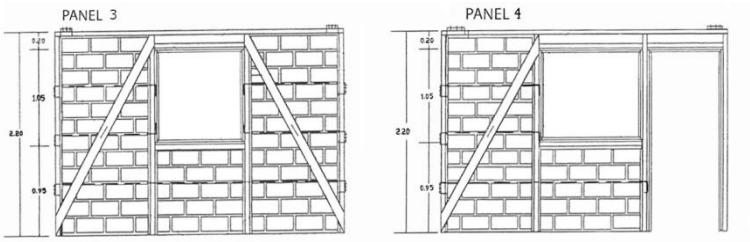


Figure 3. LAD-MA wall panels 3 and 4.

Each of the four typical wall panels consists of wooden studs and brick tiles. To allow for architectural alternatives, there is a solid wall panel, a wall panel with a centered window, a wall panel with a window, and a wall panel with a door and window. Following this same panel layout, some variations were introduced for spaces such as bathrooms and kitchens, where the heights of the sills were modified.

The system uses two types of precast brick panels, each 0.975 m wide by 0.50 m high, with alternating brick patterns to facilitate interlocking, as well as a single type of panel measuring 1.125 m wide by 0.50 m high.

4.1 Structural characteristics of the system

The LAD-MA construction system has a hybrid structure that combines the structural properties of wood and brick:

1. The wood primarily absorbs vertical loads and secondarily contributes to bracing through diagonals attached to the vertical members and the brick tiles.
2. The brick tile infill absorbs shear forces and assists in the distribution of vertical loads.
3. The steel framing ties the entire system together, allowing the wood and brick tiles to work in unison, reinforcing the masonry and connecting it to the wood and concrete structure.
4. Stucco as a finish on at least one of its faces significantly improves the panel by homogenizing the plate-like surfaces [1].

Wall panel modules composed of a wooden structure and a brick tile core from the LAD-MA construction system were subjected to reinforced concrete foundation beam tests [10] and vertical and horizontal load tests [11,12], and were certified for use in progressive housing constructions of up to two stories by the Ministry of Housing and Urban Development [13].

The design loads, calculation methods, and material characteristics were those specified in the Chilean standards: N.Ch. 1537 permanent loads and live loads; N.Ch. 431 construction and snow loads; N.Ch. 432 calculation of wind action; and N.Ch. 433 seismic design of buildings. The values obtained in these experiments were higher than the values estimated in the structural calculation [14].

The LAD-MA system was designed for two-story homes (Figure 4). The first floor uses the LAD-MA system, while the second floor uses traditional wood construction. In the early 1990s, homes using this technology were built in several municipalities of the Santiago Metropolitan Region of Chile [3] , as part of a lot densification project to accommodate two families on the same plot of land.

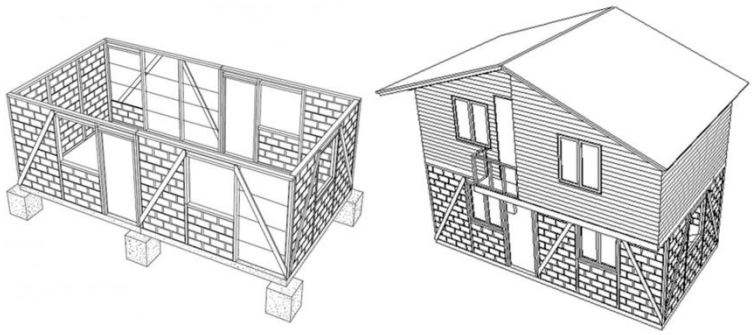


Figure 4. Isometric view of a typical construction and a typical house with a wooden second floor

4.2 Images of the construction process of a house

Significant images of the construction sequence of the homes built using the LAD-MA system (Figures 5, 6, and 7).

5 Analysis of the LAD-MA system

The following tables and analysis categories are presented according to Monjo's proposal for the Evaluation of

Construction Systems [3].

5.1 Analysis of functional constraints of the LAD-MA system

Functional constraints are those that ensure: integrity; safety; suitability; environmental comfort; and formal composition.

- Integrity against mechanical actions, climatic actions, and actions of biological agents.
- Safety against direct and indirect human actions such as pollution and fire.
- Suitability for use and construction procedures, where we consider progressivity and self-construction.
- Environmental comfort: hygrothermal, hygienic, acoustic, and visual.
- Composition: geometric and color, as the architectural potential of the system to offer design possibilities.

When analyzing the LAD-MA system under the criteria outlined above, it is observed that the potential for meeting and adapting to the constraints falls within a medium range for most variables. Regarding biological attacks (termites), it has low resistance if untreated wood is used, as was the case in the study. Fire safety is also in the low range due to its use in wooden structures with small-dimension joinery. Adaptability to use is low since it requires maintenance that users do not always perform. Notwithstanding the above, the LAD-MA system, having been designed for habitable structural work, was, in most of the cases studied, improved by user actions regarding several of the initial constraints. Regarding environmental comfort constraints, it is worth noting that the LAD-MA system meets thermal transmittance values that could be considered "high" from a regulatory standpoint, with a transmittance value of approximately 3.23 $W/m^2 K$ for walls, meaning the system is suitable for northern regions of the country but does not comply with current thermal regulations for the central and southern regions. For this reason, it has been rated as average. However, the system can be upgraded by incorporating insulating materials, preferably installed on the exterior of the walls. Regarding acoustic performance, the system does not meet the standard requiring a minimum of 45 dB(A), although its performance can also be improved. (See Table 1).

Figure 5. Prefabrication of wooden wall panels in the workshop and prefabrication of brick tiles in the workshop courtyard

Figure 6. LAD-MA wall assembly process

Figure 7. House in 1990 and house in its current state in 2018

Socioeconomic suitability is of medium rank and is unlikely to be improved, as the system does not meet high or medium socioeconomic standards. Its constructional suitability is medium; it favors assisted self-construction, although it was not found to be suitable for progressive construction, as families expanding their homes without assistance did not do so using this system. The geometry of its panels offers possibilities for architectural suitability in visual, geometric, and color aspects, and these are in the high range (see Table 1).

Table 1. Analysis of functional constraints of the LAD-MA

Alto ● Medio ■ Bajo ▲

CONDICIONANTE			POSIBILIDAD DE OBTENCIÓN			ADECUACIÓN A LA SITUACIÓN					
						GEOGRAFICO-CLIMATICA			SOCIO-ECONOMICA		
			ALTA	MEDIA	BAJA	ALTA	MEDIA	BAJA	ALTA	MEDIA	BAJA
INTEGRIDAD ANTE	ACCIONES MECANICAS			■			■			■	
	ACCIONES CLIMÁTICAS	AGUA		■			■			■	
		SOL		■			■			■	
		VIENTO		■			■			■	
	ANIMALES Y PLANTAS				▲		■			■	
SEGURIDAD ANTE	ACCIONES HUMANAS DIRECTAS			■			■			■	
	ACCIONES INDIRECTAS	CONTAMINACIÓN		■			■			■	
		FUEGO		■				▲		■	
ADECUACIÓN	DE USO			■				▲		■	
	CONSTRUCTIVA	CONSTRUCCIÓN PROGRESIVA		■			■			■	
		AUTOCONSTRUCCIÓN		■			■			■	
CONFORT AMBIENTAL		HIGROTERMICO		■			■			■	
		ACUSTICO			■		■			■	
		VISUAL	●				■			■	
COMPOSICIÓN		GEOMÉTRICA	●				■			■	
		COLOR	●				■			■	

5.2 Analysis of the construction constraints of the LAD-MA system

The construction constraints of the system relate to three phases of the process: the manufacture of components, transport to the site, and on-site assembly; a fourth phase of the process that affects the building's service life can also be considered: maintenance. The constraints related to materials, manufacturing, transportation, assembly, and maintenance intersect with the availability of materials, user acceptance, quality control, and the maintenance required for the building in question.

In the LAD-MA system, the materials—including wood, brick, and steel—are readily available, highly accepted by users, and subject to adequate quality controls. Maintenance, however, requires significant attention from users, with a medium likelihood of maintenance and a low likelihood of continuity. Manufacturing, transportation, and assembly also rank high in terms of feasibility, user acceptance, and quality control, with maintenance being the most critical aspect of

the system among its construction constraints (see Table 2).

Table 2. Analysis of the construction-related factors of the LAD-MA system

Alto ● Medio ■ Bajo ▲

CONDICIONANTE	POSIBILIDAD			ACEPTACIÓN			CONTROL DE CALIDAD			CONTINUIDAD		
	ALTA	MEDIA	BAJA	ALTA	MEDIA	BAJA	ALTA	MEDIA	BAJA	ALTA	MEDIA	BAJA
MATERIALES	●			●			●				■	
FABRICACIÓN	●			●			●				■	
TRANSPORTE	●			●			●				■	
MONTAJE	●			●			●				■	
MANTENIMIENTO		■		●			●					▲

5.3 Analysis of the technological profile of the LAD-MA system

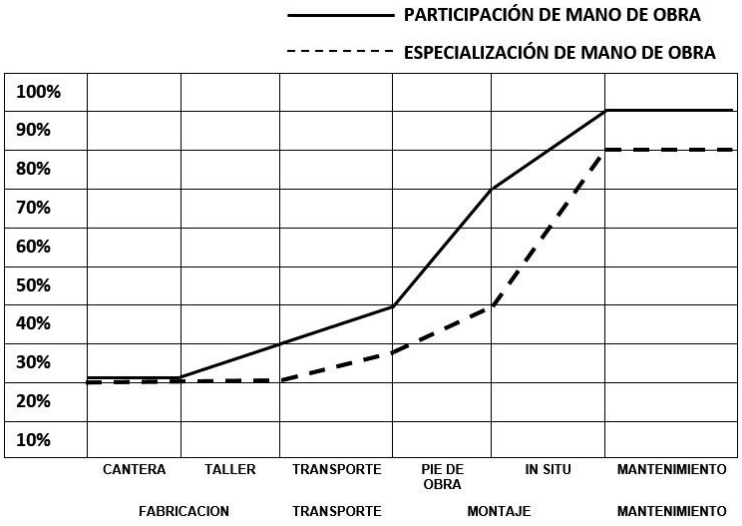
The assessment of the technological profile analyzes the impact of labor on the construction system, contrasting it with the level of mechanization or industrialization and, therefore, its technological level, while considering the economic impact of labor.

The raw materials for the LAD-MA construction system were sourced from nearby suppliers and transported to the prefabrication workshop by the suppliers themselves.

The LAD-MA system was designed to be labor-intensive, relying on unskilled labor. It uses three main construction components: foundation beams, wooden wall panels, and brick tiles. The foundation beams are molded and assembled on-site to avoid transportation and allow them to be constructed by unskilled labor under the supervision of foremen; the wooden wall panels and the prefabrication of brick tiles were carried out in a workshop by unskilled labor and also under the supervision of foremen, to be transported to the construction sites, which were scattered throughout a neighborhood.

The construction of a house using the LAD-MA system is labor-intensive, with labor accounting for around 90% of the work. The percentage of unskilled or semi-skilled labor is around 80% and consisted mainly of women. (see Table 3).

Table 3. Analysis of the technological profile of the LAD-MA system



5.4 Analysis of the subsystems of the LAD-MA system

The LAD-MA system is broken down into subsystems that could eventually be used separately. The foundation beams could support another construction system, and the wooden wall panels could contain a different infill material than brick tiles. In this sense, it is an open construction system that allows for and requires the incorporation of other commercially available elements external to the system.

Most of the subsystems in a home built with LAD-MA are incorporated on-site and are external to the system. Recall that the proposed standard home design included a first floor in LAD-MA and a second floor in wood, which in many cases was partially sourced from the recycling of substandard housing.

As mentioned, the system was designed to be a "habitable shell" completed by the users themselves through a progressive process of improvement. Its primary objective was to provide a structural envelope—both vertical and horizontal—that would allow the second floor to house an improved version of the informal housing in which the families lived. The walls of the LAD-MA system serve as the vertical structural elements, which in this case coincide with the façade enclosure (see Table 4).

Table 4. Analysis of the LAD-MA system's subsystems

Alto ● Medio ■ Bajo ▲

FACTORES ECONÓMICOS BÁSICOS		ADECUACIÓN A CIRCUNSTANCIAS ECONOMICAS LOCALES											
		POLITICO-ECONOM. (Planificación)			SOCIO-ECONOM. (Poder Adquisitivo)			TECNOLOGICAS (Nivel Industrial)			CULTURALES (Nivel de exigencia)		
		ALTA	MEDIA	BAJA	ALTA	MEDIA	BAJA	ALTA	MEDIA	BAJA	ALTA	MEDIA	BAJA
COSTE	MATERIALES	●			●			●			●		
	TRANSPORTE	●			●			●			●		
	MANO DE OBRA	●			●			●			●		
TIEMPO	DE FABRICACIÓN	●			●			●			●		
	DE EJECUCIÓN	●			●			●			●		
CALIDAD	FUNCIONAL	●			●			●			●		
	MATERIAL	●			●			●			●		

5.5 Analysis of economic conditions of the LAD-MA system

The economic conditions under which the LAD-MA system was used were those of a country with a per capita income as of 1990 of US$2,500, ten times lower than that of 2018, which reached approximately US$25,000 according to the IMF. It is under these conditions — characterized by high poverty rates — that the system was highly suited to the socioeconomic and technological situation and the level of industrial development accessible to the involved actors (NGOs and users). Furthermore, from a technical standpoint, the solution provided conditions superior to those that existed and to those the actors could have achieved with their own resources. This also explains the system's acceptability (see Table 5).

Table 5. Economic conditions of the LAD-MA system

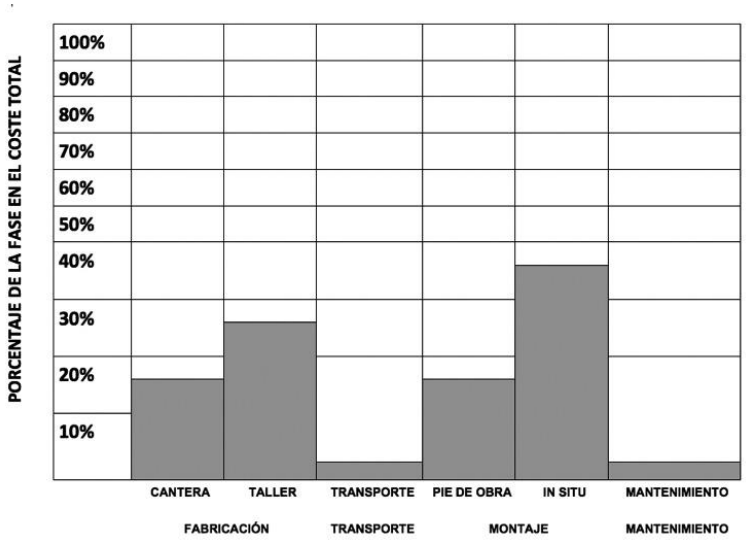
PROPIO ● AJENO ■

SUBSISTEMAS		INCORPORADO EN TALLER		INCORPORADO EN OBRA	
		PROPIO	AJENO	PROPIO	AJENO
ESTRUCTURA	CIMENTACIÓN			●	
	VERTICAL	●			
	HORIZONTAL				■
CERRAMIENTOS	FACHADA	●			
	CUBIERTA				■
	TABIQUERÍA				■
	VENTANAS				■
	PUERTAS				■
ACABADOS INTERIORES	SUELOS				■
	PAREDES				■
	TECHOS				■
INSTALACIONES	AGUA POTABLE				■
	ALCANTARILLADO				■
	ELECTRICIDAD				■

5.6 Economic profile analysis of the LAD-MA system

The LAD-MA construction system has standard quarrying and manufacturing costs corresponding to materials purchased on the market: wood, bricks, cement, aggregates, and steel. The cost of workshop labor consists of general operating expenses and the remuneration of supervisors overseeing the users' labor. User participation in all stages was calculated for the purposes of the analysis at market value, as a theoretical cost, because in practice it was unpaid labor (see Table 6).

Table 6. Economic profile of the LAD-MA system



6 Discussion

6.1 The contextual situation

The reality of Chile in 2019 in macroeconomic, social, and cultural terms is very different from that of the period in which the LAD-MA system was developed. When President Patricio Aylwin's democratic government took office in 1990, the country had poverty levels exceeding 40% of the population, with high rates of unemployment or underemployment. According to estimates by the Ministry of National Planning, there was a quantitative housing deficit of 918,756 units and a qualitative housing deficit of 666,194 units for a population of approximately 13,000,000 inhabitants. GDP has grown tenfold since then, but this has not translated into greater social equity; the Gini Index ranks Chile as the seventh most unequal country in the world [15]. The increase in multi-generational households has caused the country to regress 20 years in terms of its housing situation. The 2017 National Socioeconomic Characterization Survey showed that there is a shortage of around 500,000 homes [16]. Techo Chile [17] reports that "camps" [4] have increased by 48 percent over the past six years, with 40,541 families living in 702 shantytowns.

For decades, public housing policy has prioritized the private housing supply through demand-side subsidies. Flexible models such as direct self-construction, user participation, and progressive solutions—used in previous decades—are practically not considered. While this might seem like good news, as it could suggest that the state or the market is providing adequate solutions, it is contradicted by the data presented above.

The case of the city of Santiago is the most critical, as the capital is home to nearly 32 percent of the country's population and there is virtually no land available for horizontal expansion; consequently, in recent years there has been an explosive increase in the supply of high-rise housing, which has resulted in the so-called "vertical ghettos" [18].

The government has tentatively and tentatively launched initiatives that could open up new avenues for addressing the

housing problem faced by vulnerable sectors, such as the suite of programs known as Settlement Typologies: Land Densification [5], Construction on Own Land, and Small Condominiums, which aim to maintain family support networks, respond appropriately to the needs of diverse families, develop on well-located land, contribute to density growth by leveraging existing infrastructure and services, reduce transportation costs through proximity to workplaces and educational institutions, and promote urban equity; they also serve as an appropriate response for housing renewal in the event of natural disasters, accidents, obsolescence, and general reconstruction efforts, while fostering social integration through self-construction [19].

6.2 The role of technology in affordable housing projects

The concept of "technology" used in this article corresponds to one of the definitions provided by the RAE: "The set of instruments and industrial procedures of a specific sector or product," where—in the case of the LAD-MA construction system—the instruments and procedures employed are the modular construction elements that are prefabricated on-site and in the workshop and integrated into a construction process that utilizes assisted self-construction and mutual aid. This idea differs from the concept of "technique," which the RAE defines as: "A set of procedures and resources used by a science or an art," and has a more restricted scope than the concept of "technology."

Exploration of construction systems incorporating industrialized components has a history in Chile dating back to the 1940s, with at least 12 construction systems used in social housing through the late 1970s, closely linked to public policies that promoted their development. Among these, we highlight the "Isolita" system [20] due to its similarity to the LAD-MA system. The "Isolita" system from 1946 was based on walls constructed with 4" x 4" oak pillars between which horizontal slabs of 85 cm high lightweight concrete panels ("Isolita") were fixed. Another very important precursor to the LAD-MA system is the BENO system developed by the Experimental Center for Economical Housing (CEVE) in Córdoba, Argentina, which uses concrete pillars between which composite slabs of bricks bonded with cement mortar are placed; approximately 600 homes have been built in that country using this method.

Taller Norte maintained that, given the magnitude of the housing problem, any solution was a good one: self-construction, cutting-edge and alternative technologies, construction systems based on mud, brick, wood, reinforced concrete, among others. The best solution would be one that encouraged the organized participation of the user, in the full exercise of their rights and with respect for their traditional knowledge. It stated that the option to be adopted by the "Construyendo Juntos" committees should be communicable, learnable, and operable by the users themselves within a participatory vision of human, economic, administrative, and construction-related relationships in the territory [7]. This idea implies that no system can serve as a universal solution to be applied across different times and contexts. A constructive technology must adequately address the problem it seeks to solve, and be appropriate and adaptable in the terms proposed by Massuh [21].

Technology has intentionality; it responds to interests of various kinds and can be a driver of development or a source of dependency. Traditional technologies are those that can be passed down through generations and in which changes occur slowly and with minor variations. Among these are wooden constructions and various types of masonry—such as adobe, bricks, and stone blocks—which, by their nature, are essentially artisanal, involving extensive on-site labor without significant technological sophistication and intensive use of labor (Massuh, 21).

Based on these premises, technology is understood as a means and not an end in itself; within a specific socioeconomic-cultural framework, it forms part of a complex process of habitat production as well as one of its components, with collective organizational processes being of the utmost importance, where a sense of community takes precedence over individualism in the construction of the habitat. This idea falls within the conceptual framework of the

social production of habitat — a concept that has been in use since the 1970s and was primarily disseminated by HIC (Habitat International Coalition) [22].

A compelling example of the application of this approach on a medium scale is the experience in innovation and technology transfer of CEVE, which, with its 44 years of existence, constitutes a valuable benchmark, both for its prodigious production of new construction technologies and for serving as a management model for the social production of habitat.

7 Conclusion

"Housing construction technology is closely linked to the social and economic processes of a community, as well as to the knowledge and experiences of which it is the depository"

Architect Víctor Basauri [6]

From the study of the LAD-MA construction system, we can infer and agree with Monjo's [3] proposal for the Evaluation of Construction Systems that it is necessary to analyze a set of aspects inherent to its materiality, which he defines as Functional Conditions. These include integrity against mechanical and climatic forces, response to fire safety issues, pollution, and human or biological agents, as well as the system's ability to adapt to the geographical and climatic environment and, in particular, to the socioeconomic conditions of the time and place where the system is used.

Part of the research not presented in this article but which informed the analysis of the construction system is the detailed survey of the current condition of six of the homes built in the 1990s using the LAD-MA system, as it confirmed many of the system's initial premises, such as being a phase of a progressive solution within a process of housing improvement. The families gradually plastered the LAD-MA walls with cement mortar, thereby improving their initial thermal and acoustic insulation, while also enhancing the brick's weather resistance.

It was found that all the homes had been expanded, but that LAD-MA was not used in any of them, which made it clear that the construction system failed to meet one of its premises: that users would be able to take ownership of the technology. Users consulted on this matter stated that they found it easier to use wooden frames clad with particleboard, as they lacked the support of technical assistance and the collaborative work of their neighbors. In this case, Massuh's [21] assertion holds true: traditional technologies are those that can be transmitted across generations and in which changes occur slowly and with minor variations.

It was found that both the structural calculations and the laboratory tests to which the panels were subjected met design expectations. The homes withstood the powerful 2010 earthquake, one of the largest earthquakes in history that struck south-central Chile, with a magnitude of 8.8 on the Richter scale. During that earthquake, recently constructed reinforced concrete buildings collapsed.

It was found that maintenance plays a very important role in the state of preservation and integrity of homes built with LAD-MA. Homes whose wood was regularly painted and varnished are in very good condition, unlike those homes where no maintenance was performed; in these cases, the wood suffered degradation due to ultraviolet rays and termite infestation.

Through an analysis of functional, structural, technological, subsystem, and economic conditions and profiles, it was possible to conclude that the LAD-MA construction system, as a technological innovation designed to address a specific problem, within a specific socioeconomic, political, and cultural context, responded appropriately to the historical, social, economic, cultural, and political conditions of its time.

The system utilized materials available in its environment that were accepted by users. The system made intensive use of the most readily available resource at the time: the labor of the participants themselves. The requirement of being environmentally friendly was met through the use of renewable materials such as wood and, in many cases, the recycling

of the original makeshift housing.

The technology is simple and easy to learn; it facilitated the participation of unskilled labor through mutual aid and self-construction. Housing production was supported by social management, strengthening community action.

The production process drew on the accumulated experience and know-how present in the local culture, addressing the needs, aspirations, and desires of a poor community. This was complemented by technical assistance from professionals and technicians, support from a component prefabrication workshop, a materials bank, a tool bank, and financial support.

With the advent of democracy, there was rapid economic growth and rising expectations among the people regarding the role the State should play in solving their problems. Faced with this scenario, NGOs involved in social development processes gradually lost relevance; many of their professional staff moved to the public sector, and the financial support that came from international cooperation dwindled until it disappeared.

The main advantage of the LAD-MA construction system under the conditions of its application was that it enabled assisted self-construction processes using low-cost materials while ensuring adequate quality controls. The main limitation of the LAD-MA system under the country's current conditions is that it does not meet the thermal and hygienic requirements established by current regulations; however, it has the potential for improvement, a topic we explore in greater detail in a complementary study to this one.

Since the construction system analyzed is the result of an NGO's innovation, no projects were carried out in other geographical contexts beyond the areas where Taller Norte operated, and there was no continuity following its closure.

The LAD-MA system can be relevant under the country's current social, economic, cultural, regulatory, and technological conditions if the following conditions are met: that public policy prioritizes non-profit intervention models; that it incorporates the variable of user participation; that there is adequate professional and technical assistance supported by a minimum infrastructure for the prefabrication of components; and that improvements and updates are made to bring the system into compliance with current regulations, particularly regarding hygrothermal conditions. The next phase of the research will focus on evaluating alternatives for improving the LAD-MA system, with a view to its potential use in other countries around the world.

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Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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Note

[1] This program received the LIGURIA International Prize 1988, awarded by the International Center for People's Development. Genoa, Italy.

[2] The 'fiscal brick' is a handmade fired clay block measuring 28.5 x 14 x 7 cm. It is widely used in the construction of houses and other buildings in Chile.

[3] At this stage of the research, it was not possible to find documentation on the number of houses built with the LAD - MA system.

[4] Precarious and illegal settlements generated from the occupation of public or private land.

[5] This program has its background in the pilot experience developed by Taller Norte in the early 1990s.

[6] Architect Víctor Basauri Tocchetton was one of the founders of Taller Norte and its director.