

TIMBER HOUSING PRODUCTION SYSTEMS IN BRAZIL

Victor A. DE ARAUJO¹ João C. BIAZZON¹
Juliana CORTEZ-BARBOSA² Elen A. M. MORALES²
Maristela GAVA² José N. GARCIA³

Abstract: *This paper is based on an evaluation of the industrialization levels and main production systems of Brazilian timber housing producers. Two methods were used to investigate this understudied topic. Literature-based projection was carried out to identify the production system of each sampled company, from the construction technique(s) produced by the same. The second method consisted of face-to-face interviews to identify the current production system of each producer. For both methodologies, the timber housing sector presented a considerable level of industrial development in view of the greater popularity of prefabrication systems. Due to admissions to enable the system identification from the literature-based projections, a result contrast in artisanal production was verified between both methodologies. Despite the sampling difference, the two methods showed typical results for the industrial processes. Thus, few artisanal developers and the visible amount of industrial-based producers could regard this sector as industrial-featured.*

Key words: *housing, wood, manufacturing type, sampling, sectoral survey.*

1. Introduction

Good arguments have been indicated by several authors to intensify greater timber uses. For example, Bejo [2] suggested that wood materials for building lead to much lower embodied energy and carbon dioxide emissions, when compared to

inorganic materials. Ramage et al. [30] detailed that wood can naturally have economic benefits, as modern timber is factory produced and brought to site for rapid assembly.

Over time, wood has been brewed from industrial advancements [7]. Civil construction has benefited from this

¹ Research Group on Development of Lignocellulosic Products (LIGNO), São Paulo State University (UNESP), Campus of Itapeva, 519 Geraldo Alckmin, Itapeva (SP), Brazil;

² Department of Timber Industrial Engineering, São Paulo State University (UNESP), Campus of Itapeva, 519 Geraldo Alckmin, Itapeva (SP), Brazil;

³ Department of Forest Science, University of São Paulo (USP), Luiz de Queiroz College of Agriculture, 11 Pádua Dias Avenue, Piracicaba (SP), Brazil;

Correspondence: Victor De Araujo; e-mail: engim.victor@yahoo.de / victor@usp.br

evolution.

The self-built housing production aimed at simple and straight solutions, which were also subordinated to the construction rules of immigrant and migrant carpenters [37]. From the intensive logging mechanization and proliferation of sawmills in the 1850s in southern Brazil, the standardization of building elements and wood architecture propagation were possible indeed [13].

2. Bibliographic Background

2.1. Timber Housing Aspects

A housing construction system based on lignocellulosic raw material coincides with process(es) that integrate(s), with balance and consistency, set(s) of structural parts and subsystems made with wood, bamboo, natural fibres, and composites [5]. Timber houses are industrializable and flexible.

Modern building techniques preferably use standardized wood-based composites and structural lumber [5]. In contrast, these construction products are not

habitual in Brazil. This reason was cited by Scanavaca Junior and Garcia [33], since several local sawmills still have low reliability, due to lack of technological results.

Therefore, studies on product developers are important matters for the forest chain.

2.2. Timber Housing Production Systems

Timber housing production is essentially based on machining and/or processing of structural parts [6], [8]. Wood-based housing construction techniques are ordered under production system. On-site and off-site are examples of building parts production.

In this direction, Piqué Del Pozo [27] regarded two different production aspects: industrial plant and building site (Table 1). Five production systems were identified under industrialization level, which varied from the highest industrialization to on-site house assembly, i.e., from greater to lower level.

Production systems of timber housing and main characteristics Table 1

P ↓	Production System	System Feature	O ↑
	Vernacular	Free-industrialization with input production on-site	
	Semi pre-cut	Reduced industrialization with strong work on-site	
	Pre-cut	Lumber prefabrication with parts adjustments on-site	
	Part and Panel prefabrication	High industrialization of panel and prefab parts off-site	
	Volumetric prefabrication	Full industrialization off-site for on-site module fusion	

P: plant production (off-site); O: on building site production (on-site)

Source: adapted from Piqué Del Pozo [27]

Using the production features (Table 1) and technical observations in the Piqué Del Pozo [27] and De Araujo et al. [5], [11]

studies, timber housing techniques can be ordered according to Table 2.

Production systems of timber housing according to housing technique Table 2

Production System	Timber-based Housing Construction Technique
Vernacular	Half-timbered frame; stick with masonry
Semi Pre-cut	Log-home; clapboard with wainscot
Pre-cut	Horizontal clapboard between studs; nailed clapboards (hor/ver)
Part and Panel Prefabrication	Post-and-beam; woodframe (balloon/platform/mixed examples)
Volumetric Prefabrication	Modular house (woodframe/CLT/for building site); mobile home

Hor: horizontal scope; Ver: vertical scope; CLT: cross-laminated timber panel

Sources: adapted from Piqué Del Pozo [27] and De Araujo et al. [5], [11]

2.3. Justification and Objectives

Over time, there have been demands for sectoral studies worldwide, mainly in the wood chain.

Many surveying examples have detailed the conditions of people and sectors regarding the timber scope, for example, German people's attitudes about timber materials and house uses [14], Kosovar forestry and sawmilling [1], wood-based pallets and crates for the European agroindustry [36], Croatian and Slovenian buyers of wood-based kitchen furniture [19], eco-innovation in Slovenian enterprises [16], the Polish furniture industry [12], the chains of custody for the Croatian wood industry [17], Brazilian prefabricated wood housing [29], furniture selling places in the Croatia-Slovenia-Slovakia region [28], job satisfaction in the Spanish wood and paper industry [32], job satisfaction about the Slovakian furniture industry [20] etc.

The importance of industrial studies and studies about production aspects can also be justified by the remark made by Matičević and Lovrić [22], who have emphasized that the access and survival of any developer on competitive international markets depend on the level of logistics and production.

The timber housing production sector is still understudied, requiring additional analyses to identify the current Brazilian panorama. The sectoral development is

hindered due to a visible lack of formal associations and few studies on this topic.

Only two studies are available for the Brazilian view, that is, an evaluation about São Paulo state [34] and a report for the prefabricated timber houses in Brazil [29]; these studies have somewhat limited approaches concerning the industrial aspects.

A broad characterization was specifically carried out to characterize the timber housing production sector in Brazil, which included different discussions. This broad sectoral survey was standardized from face-to-face interviews with local producers to identify features and gaps for each approach.

In order to support its development, this broad survey provided scientific papers to characterize this sector from distinct viewpoints. In addition to the present paper, the other survey-related papers addressed: the economic and labour size of producers [9]; the market availability of timber housing techniques [11]; machinery type, size, and obsolescence [8]; and sectoral difficulties and corrective actions [10]. Despite a synergy, the results are not necessarily related to each other.

This paper includes an approach to identify the industrialization levels and main production systems of timber housing producers in Brazil. The study was based on two methodologies: a literature-based projection from data collected in a related paper and a face-to-face interview-based survey (broad sectoral

characterization).

These different tools aimed to evaluate the production features of each sampled developer, whose results were compared to verify the differences between these tools.

Two hypotheses were listed:

- More producers with industrial plants were identified than those focused on building site production;
- Despite some primitive productions, there is a predominance of systems with visible industrialization level.

3. Materials and Methods

Brazil was considered as the area of study in this sectoral panorama. In view of the lack of sectoral reports and representations, this survey started from a listing compilation through website searches, over a year, to identify producers and features [8-11].

With respect to the methodology applied in this paper, two strategies were followed to create a reliable analysis by a comparison of perspectives: literature projections based on the available timber houses and their possible production systems; and a sectoral survey from face-to-face interviews with producers. The methods are detailed below.

3.1. The Literature-Based Projection Method

This method was developed to establish a synergy with results from other approaches related to the same broad sectoral survey. Listed in Table 3, the results related to the market availability for timber housing techniques were regarded to ascertain the possible production system of producers, using literature precepts cited in Table 2. The cited results (Table 3) were obtained by De

Araujo et al. [11] for a triangulated comparison based on two different data sources: searches on producers' websites and a face-to-face interview-based survey. Thus, the results from the literature projections included the other methods considered only in the study cited in Table 3.

From arguments by Piqué Del Pozo [27] and De Araujo et al. [5], [11], the projection method served to bibliographically identify the production system of each developer.

In short, all timber housing techniques (Table 3) were ordered according to their respective production systems (Table 2) using data from the aforementioned studies.

3.2. The Interview-Based Survey Method

Despite the classification of production systems (Table 1) by Piqué Del Pozo [27], the current scenario in Brazil includes many industrial singularities as verified by De Araujo et al. [6], [8]. Another classification adapted to the local reality was required.

In Brazil, timber housing developers are available in five production configurations:

- Fully on site: artisanal stages which only occur on the building site;
- Mixed on site with own plant: some stages on an industrial plant mixed with stages performed on-site;
- Mixed on site with a partner plant: a partner makes parts to be adjusted and assembled on site by the producer;
- Fully industrialized on own plant: parts are industrially manufactured "off-site" to produce prefabricated kits to be assembled only on-site;
- House maker in partners' network: as in automakers, the producer is only responsible for building assembly and the parts are made by partners.

Timber housing technique offering in sampled producers Table 3

Wooden Housing Technique	Offer in Sampled Companies [%]	
	Search on Websites*	Face-to-face Interview**
Woodframe Balloon	1.93	2.80
Woodframe Platform	12.08	17.76
Mixed Woodframe	1.93	2.80
Modular Woodframe	1.45	2.80
Log-Home	4.35	5.61
Horizontal Clapboard Between Studs	29.95	31.78
Nailed Horizontal Clapboards	48.79	42.99
Nailed Vertical Clapboards	28.50	37.38
Half-timbered Frame	0.48	0.93
CLT Modular	0.48	0.93
Modular for Construction Site	2.90	4.67
Clapboard and Wainscot	12.08	10.28
Mobile Home	0.48	***
Post-and-beam	5.80	10.28
Stick with non-structural masonry	4.35	7.48

*Margin of error $\pm 0.41\%$; **Margin of error $\pm 3.325\%$; ***not evaluated

Source: adapted from De Araujo et al. [11]

These configurations were considered to evaluate the aspects excluded from Table 1, inserting every producer on the topic studied. This ordering is suitable for the Brazilian context which includes mixed production. The Piqué Del Pozo [27] levels described in Table 1 were also regarded in this process.

Using the broad sectoral survey method, the configurations were considered to

identify scientifically, per company, the production system in use (Table 4).

In the broad survey, different questions were developed by the survey manager (first author), his advisor (last author), and the co-authors. From this survey, a query was selected to be studied in this paper (Table 4), whose five closed-answers were given to be singularly declared per interviewee.

Details of questionnaire applied for sampled entrepreneurs Table 4

Considered Question	Listed Alternative of Production System
Which is the industrialization level of your company used in the production of such timber house(s)?	Fully on site; Mixed in own plant and on site; Mixed on site and partner plant; Fully industrialized on own plant (off-site); Housing maker in partnership network

The manager was responsible for the survey performance. All authors contributed to the data analysis and discussion. The survey stages were carried

out in accordance with the methodology designed by De Araujo et al. [8-11] for every approach within the characterization of the studied sector.

The interviews were performed together with the main entrepreneur from each company. The macro region with six Brazilian states (São Paulo, Minas Gerais, Distrito Federal, Santa Catarina, Paraná, and Rio Grande do Sul) and 92% of the whole studied sector were selected as the main research area. All the producers in this region were contacted by phone. Randomly, each producer decided to take part in the survey, respecting own availability and motivation [8-11].

Data collection from the search on the websites was not possible due to the lack of information on the websites about the production systems used.

3.3. Result Analysis for Both Methods

The literature-based projections and the face-to-face interviews formed the sampling scenarios to be studied. The qualitative results from both methods were converted to percentages. The respective margins of error were obtained using the statistical software Raosoft

Sample Size Calculator. As such, 95% confidence level and 50% response distribution were considered in accordance with the prescriptions from Raosoft [31]. A similar strategy was used by De Araujo et al. [8-11].

Both methodologies analysed the same producers from distinct locations, and they achieved representative sectoral samplings. Due to the different sampling scenarios, a result triangulation was possible.

4. Results and Discussions

4.1. Verification of the Main Production Systems from the Literature Perspective

The first stage considered all timber housing techniques available in Brazil by producers (Table 3), using results from De Araujo et al. [11] and the literature support (Tables 1 and 2) to identify the production systems present in this sector (Figure 1). In short, the results listed in Table 3 were regarded to create possible projections (Figure 1).

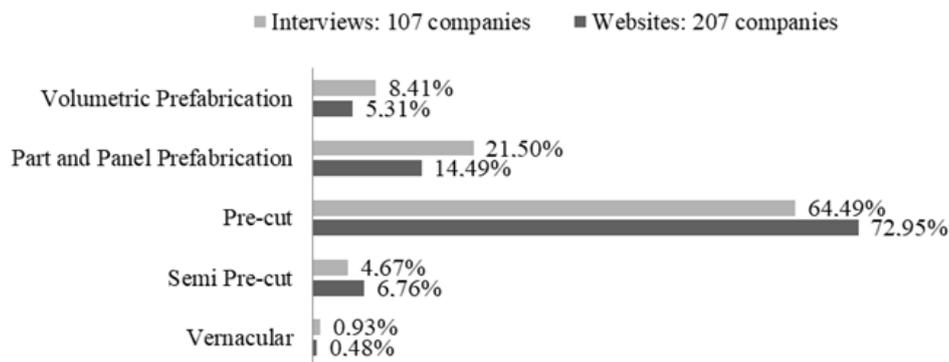


Fig. 1. Production systems from Brazilian producers using literature considerations (margins of error of $\pm 0.41\%$ for website search and $\pm 3.325\%$ for interview survey)

From the information showed in Table 3, there was only a visible difference between the popularity of the second and

third most available techniques. That is, nailed vertical clapboard houses and horizontal clapboard between studs. The

situation was attributed to the sampling similarity (interviews and website searches) verified by [11].

Also, woodframe platform construction, common in North America as declared by [35], achieved the fourth more popular position, consolidating its local presence. The noticeable presence of platform-type could be the result of its advantages, cited by [18], as the use of compact timber elements with simple cut, nailing fixation, reduced and unskilled labour, basic carpentry tools. In contrast, the clapboard and wainscot technique, known for its lower technology [5], [37], was also popular (Table 3).

Thus, the consideration of the results from another paper related to this broad sectoral survey on the technique availability (Table 3) and the production systems for each timber housing technique identified by two studies (Table 2), the literature projections about the production system was identified in Figure 1. This analysis was efficient and showed data similarities for both methods used by De Araujo et al. [11] in their study.

While these producers could offer more than a house technique, they usually have a single production process. Therefore, only a production system for each producer was regarded: the most evolved system.

Through this strategy, it was possible to observe that several timber-based housing techniques utilized a more elementary production, i.e., the pre-cut system (Figure 1), whose proposal is based on processing logs into sawn wood (blocks, lumber, etc.) with perceptible final adjustments on the building site [27].

A pre-cut system is more advanced than vernacular and/or semi pre-cut systems which present major production rusticity. However, this processing is also considered a simpler and lower technological process of housing production. For pre-cut systems, Piqué del

Pozo [27] cited the use of heavy machines for sawmilling and the processing of lumber and blocks into sawn elements.

Houses based on the pre-cut system, nailed clapboards (horizontal and vertical styles) and horizontal clapboards between studs, consolidated as the main three construction techniques in the studied sector (Table 3). Even with fewer technological advances, these construction techniques were already specified by Mello [23] and De Araujo et al. [5] as pertaining to the contemporary style.

At least 5% of the sampled entrepreneurs demonstrated to offer techniques based on rudimentary production systems such as semi pre-cut and vernacular (Figure 1). Such construction examples indicated high levels of artisanal production on the building site (e.g., wood cutting, drilling, finishing, assembly, and fixing). These processes use tools and small equipment and machinery which include axes, hammers, bucksaws, circular saws, drilling, portable machines, and others cited by [6], [8]. Thus, the timber housing techniques related to rudimentary systems are: the half-timbered frame, log-home, and clapboard and wainscot houses.

Around 20 to 30% of the companies in both methodologies (interviews and websites) consisted of contemporary timber housing techniques obtained from modern systems (Figure 1), based on standardized parts and panels, or even on volumetry (Table 1).

These systems require updated or recent machines, and they use standardized sawn wood and engineered composites as the main wooden materials for their housing manufactures. In these advanced processes, four woodframe styles (balloon, platform, mixed, and modular), modular on cross-laminated timber (CLT), post-and-beam, modular for

building site and mobile home typified the contemporary houses produced from prefabrication systems, being based on parts without artisanal stages or on two- or three-dimensional volumetric modules.

Due to lower Brazilian industrialization compared to any developed country, some producers can have lower industrial levels by reason of different housing techniques produced from the same production line.

However, inverse situations with greater industrialization levels could be possible. The analysis using the production system view showed a reference from the literature usually applied to nations with a developed industry.

4.2. Verification of the Main Production System from the Survey Perspective

The interviewing process made progress by face-to-face mode between the survey manager (the first author interviewer) and

each sampled entrepreneur (the owner interviewee). This survey utilized a questionnaire with a single structured question to be performed *in loco*. Five closed-answers were formally indicated for each interviewee who was required to provide a single response from five alternatives listed in Table 4.

More than two hundred companies were prospected, among which a representative sampling was also achieved in this survey: 50.95% of the sector was formally sampled (Table 5) and the respective margin of error was practically ideal as prescribed by [26].

According to the interviews (Figure 2), over 40% of interviewees declared a complete industrialization on own plants. Therefore, this outcome suggests that Brazil has some industrial development in this sector.

Sectoral population and sampling from the interview-based survey Table 5

Result	Amount (Producer)	Margin of Error [%]
Estimation of overall sectoral population	210	–
Samples performed in the interviewing process	107	6.65

Sources: adapted from De Araujo et al. [8-11]

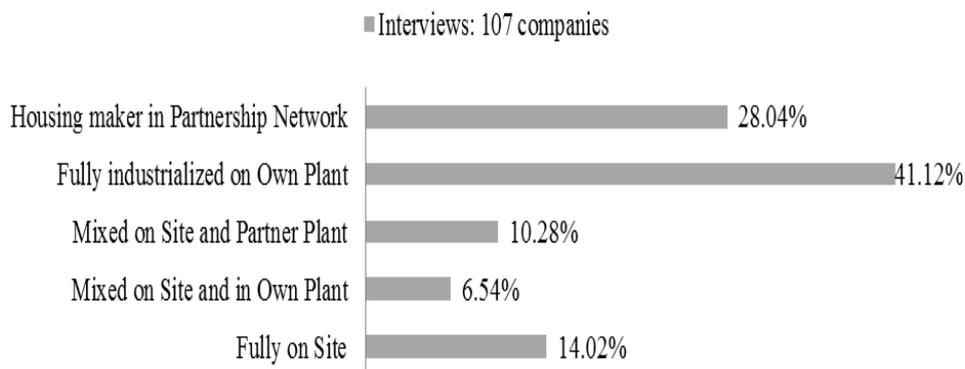


Fig. 2. Production systems from Brazilian producers using face-to-face interviews.

In 28% of the sampling ($\pm 3.325\%$), there is the development of own activities as housing maker, whose building production included the participation of other actors (suppliers and timber companies) for the preparation and prefabrication of many or all timber parts and composites (Figure 2).

One-sixth of the producers presented mixed production whose configuration has parts production and house assembly on-site mixed with prefabrication stages from own- or partner-plants (Figure 2). Despite the activities on site, this system presents a certain industrialization level which varies according to investments and technologies.

Lastly, artisanal productions (made fully on building sites) were present in 14% of producers (Figure 2). This system presents low production potential, since it enables a higher level in product customization, and does not require industrial infrastructures; it exempts investments in heavy machinery and buildings (sheds, tanks, silos etc.).

4.3. Brazilian Timber Housing Production Sector: Current Industrialization Level

From the results obtained by using the survey method (Figure 2), this sector could also be characterized under industrialization level, being that: 92 (85.98%) producers declared some prefabrication status; 51 (47.66%) concentrated on own plants; and 41 (38.32%) showed prefabrication activities made in plants from other(s) commercial partner(s); thus the results confirmed the hypotheses.

This scenario is quite different from that observed by Punhagui [29] where 42% of companies had own plants and 18% of them purchased inputs from third parties. There was a noticeable difference because Punhagui [29] only considered producers of prefabricated wooden houses, while

the present study considered a more complete analysis across the timber housing sector.

Analysing the results obtained from two methods (literature-based projections and survey based on face-to-face interviews), it is worth emphasizing that several timber-based housing techniques can already be produced industrially in Brazil (Figures 1 and 2). This scenario also revealed a sector with different production systems, whose predominance is formed by manufacturing processes. This fact contrasts with the slow industrial evolution of wood processing as cited by Zani [37] and De Araujo et al. [5].

However, the fully artisanal productions on-site reported a perceptible difference in relation to the two methods. Plant-processing absences were verified in 14% of the sampled interviewees (Figure 2) and 5% of the companies with rustic productions (semi pre-cut and vernacular systems) as verified by the projections from the descriptions in the literature (Figure 1). Considering the margin of error in the interview method, no similarity was confirmed for the analysed variable.

Furthermore, this percentage difference among artisanal production systems could also be attributed to the admission of the exclusive choice of the most evolved productions, when companies simultaneously declared the availability of different architectural styles, i.e., traditional and contemporary. In this case, some studied producers may use inferior production systems to obtain modern housing styles or vice versa.

Another fact can be related to this view: the Brazilian industry generally has a lag [15] which is marked by chronic situations due to local difficulties and bureaucracies [3], and technical and financial issues.

Due to the negative factors mentioned, some entrepreneurs are exposed and/or

forced to produce more advanced house techniques from rustic and/or obsolete manufactures. Therefore, strategies to promote the industry could reverse this domestic lag.

For this, Lucas Filho [21] prescribed that it is necessary to know the behaviour of a production system and predict the best operational conditions to suit the requirements.

In general, every industrialized housing system can be described as a very efficient alternative to build on construction site, but the respective market is still small in Brazil when compared to own potentials [25]. A great opportunity may emerge for the technological improvement of construction in developing nations, for example, Brazil, through timber housing techniques with higher industrialization levels [4], [7].

Industrialization in wooden construction could be derived from the automotive industry and its production practices which, if well applied and adapted to the forestry scenario, could culminate in the advancement of timber uses.

Automakers form a competitive market exposed to economic oscillation, requiring process tools (e.g., Just-in-Time and Lean) to increase efficiency and to reduce stocks [24]; but such practices would be complex for the forest-timber sectors which are used to suffering because of the weather in wood harvesting and transportation, and with unpredictable behaviour of sawn wood in its processing.

Inputs and product deliveries in shorter terms, product standard controlled quality, competitive costs regarding other housing techniques, and technological incentives shall summarize the aspects to be considered.

These facts aim at the mutual development and timber consolidation on the local and foreign markets. Stimuli for efficient practices to increase the housing

quality and production shall include all producers, especially those based on compact and artisanal systems.

5. Conclusions

The Brazilian timber housing sector could not be as virtuous as the identical industries from Europe and North America, but it can be considered a production sector formally contained in the domestic industry. Still, its existence was evinced through the typical results obtained from two methods tested in this paper: a face-to-face interview-based survey and literature-based projection.

In both methodologies, over two hundred timber housing producers were prospected. The timber housing sector already presents an industrial standard in Brazil as evinced by the outcome comparisons from the two methods.

Literature-based projection suggested the existence of productions based on artisanal systems (vernacular) as well as industrial processes (volumetric prefabrication, part and panel prefabrication, semi pre-cut, and pre-cut). However, this evaluation verified that few companies have produced houses from artisanal processes. It also suggested that the Brazilian timber housing sector has been directed to industrial productions.

The survey based on face-to-face interviews evaluated a representative part of the sector and also identified a predominant presence of industrial processes. All five production systems mentioned in this evaluation were visibly identified in the sectoral sampling. However, this survey also confirmed that producers were mostly focused on housing prefabrication as suggested by the projections. With respect to artisanal producers, the survey method identified more artisanal producers than projections, being essentially justified by the admission

of a single system for producers based on traditional and modern houses.

The Brazilian timber housing sector is broad and has perceptible industrialization level, because several producers declared partial or full productions from industrial plants.

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