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Original Article

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My Wooden House: Unit Cost of Popular Housing in Acre state, Brazil

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ABSTRACT

Housing deficit is a problem that affects low-income populations in Brazil, with over 6 million families affected nationwide and approximately 631 thousand in the North region of the country. Ordinance no. 318/2014 of the Brazilian Ministry of Cities authorized the construction of popular housing using timber as raw material in that region. The objective of this study was to establish the unit cost of a wooden dwelling, referenced in the project Popular Wooden Housing (PWH) developed by the Laboratory of Forest Products and the University of Brasília (UNB) for the National Rural Housing Program (NRHP). The Basic Unit Cost (BUC/m^2) methodology was used, with collection of prices in Rio Branco, capital of the state of Acre, for composition of the Final Unit Cost (FCU/m^2) of a wood construction. Mean cost of R$ 934.52/m^2 was observed from September 2015 to April 2016. Feasibility of wood construction was demonstrated by a final cost per m^2 28.06% lower than that of a conventional masonry house.

Keywords: NRHP Popular Wooden Housing, social housing, costs.

1. INTRODUCTION

Right to housing, ensured by the Constitution of the Federative Republic of Brazil, is a fundamental element for the consolidation of public housing policies (Brasil, 1988). To meet this demand, the Government launched the Program *Minha Casa, Minha Vida* (PMCMV) in March 2009 with the purpose of reducing the housing deficit in the country, estimated in 6 million homes, and offering housing opportunities to low-income citizens. In the same year, the National Rural Housing Program (PNHR) was created and regulated within the PMCMV, aiming to assist 685 thousand families in the rural area (Brasil, 2016).

In 2012, representatives of the Extractive Communities of the North of Brazil requested PNHR managers with regard to the possibility of building their dwellings using wood as main raw material. In this context, in order to offer solutions to fill this gap and make the use of wood as construction material feasible within the scope of the PNHR, a group composed of representatives and technicians from several areas of the Government, researchers from the Forest Products Laboratory (LPF) – a research center of the Brazilian Forest Service (SFB) –, and professors from Brazilian universities was formed with the objective of discussing the theme (SFB; LPF, 2013).

The result of this discussion was the presentation of a technical proposal that culminated in the preparation and publication of Ordinance no. 318/2014 by the Brazilian Ministry of Cities addressing the use of wood in the construction and repair of dwellings within the PNHR/PMCMV. The technical proposal of this Work Group was based on the project Popular Wooden Housing (PWH) developed in 2002 by the LPF in partnership with the University of Brasília (UnB) (Melo et al., 2002; SFB; LPF, 2013; Brasil, 2014).

The conception of this project did not include costs, in spite of the construction of several housing units in the municipalities of Pimenta Bueno, Espigão do Oeste, and Pimenteiras in the state of Rondônia, Manacapuru in Amazonas state, and Paragominas in Pará state. These costs were not estimated because of the use of wood seized and donated by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) and use of unpaid labor provided by the homeowners within the Solidary Community Program (Melo et al., 2002).

Therefore, the present study seeks to demonstrate the Final Unit Cost (FUC/m^2) of a popular wooden house using as reference the methodology of Basic Unit Cost (BUC/m^2) applied in the construction of conventional masonry popular houses and standardized by the Brazilian Association of Technical Standards (ABNT). Thus, the objective was to demonstrate that the costs of building popular wooden dwellings, especially in the North region of Brazil, meet the purposes of the PNHR, and are economically more attractive than those for construction of a similar masonry dwelling.

2. MATERIAL AND METHODS

2.1. Characterization of the study area

The state of Acre, located in the extreme west of Brazil, occupies an area of 164,123 km^2, integrates the North region, and borders the states of Amazonas and Rondônia, Bolivia and Peru (IBGE, 2010).

According to the estimates of the Brazilian Institute of Geography and Statistics (IBGE), the state of Acre had 733,559 inhabitants, with 532,279 of them living in urban areas and 201,280 in rural areas in 2015. The general housing deficit was 29,939 households, with more than 17,000 in the state capital and rural areas. The average number of citizens per household was 3.82. The state capital, Rio Branco, is the largest and most populous city in the state, with a population estimated by the IBGE of 370,550 inhabitants in 2015, and the sixth largest city in the North region of Brazil. It is 8835 km^2 large, approximately 153 m above sea level, and distant 3105 km from Brasília (IBGE, 2015).

The choice of Acre state was due to the knowhow of the Technology Foundation of the State of Acre (FUNTAC) on the construction of popular wooden houses (FUNTAC, 2003); timber production in the region, which includes the municipalities of Rio Branco, Capixaba, Epitaciolândia, Sena Madureira, Senador Guiomard, and Xapuri, of approximately 193,000 m^3/year (SFB; IMAZON, 2010); and a rural housing deficit that can be met within the scope of the PNHR.

2.2. Data collection

Based on the PWH project, the study development can be divided into three distinct stages, as described in Table 1.

The timber companies that collaborated in the market price collection at the time processed the wood characterized by the LPF according to Table 2, as well as Cambará vermelha (*Lantana camara* L.) and Castanharana (*Eschweilera atropetiolata* S. A. Mori), all high-density, fungus-resistant hardwood of higher commercial value (Souza et al., 2014). These were the wood species considered in this study.

Cost estimation of the materials specified in the electric, hydraulic and sanitary projects was conducted through collection of market prices using the National System of Costs Survey and Indexes of Construction (SINAPI) in the same months of the wood market price collection, that is, from September 2015 to April 2016.

2.3. Composition of the Final Unit Cost (FUC/m²) for popular wooden housing based on the Basic Unit Cost (BUC/m²) for a popular R1B house

The unit cost of a popular wooden house has not yet been regulated by the ABNT. Thus, a choice was made to use the Basic Unit Cost (BUC/m²) normalized by the ABNT NBR 12721:2006 norm for conventional masonry constructions as a reference, considering that

Table 1. Stages of the proposed study.

Implementation stages	Systems, organizations, suppliers, and collaborators involved	Results achieved
1 – Visit to Rio Branco to demonstrate the project and sensitize the parties involved in August 2015	SINDUSMAD-AC; SINDUSCON-AC; FUNTAC; FIEAC; 10 timber companies and sawmills; 04 construction material retailers.	Forwarding of spreadsheets with quantities of timber and other construction materials of the PWH project to attain market price collection
2 – Market data collection	Timber companies: Índia Porã; Triângulo; Madeirense. Retailers: Agroboi; Barriga Verde; Parafusão. Undergraduate student majoring in Economics at UFAC.	Monthly collection of prices from timber companies, sawmills, and construction material retailers
3 – Preparation of electrical, hydraulic and sanitary projects	Collaborating civil engineer, professional registration no. CREA -180.161.895-0.	Preparation of spreadsheets with quantities of materials, based on the projects, and treatment of all data using Microsoft Excel® 2010 software

Table 2. Technological characterization of the wood included in the study.

Wood	Density	Durability	Use
Cumaru *Dipteryx odorata* (Aubl.) Willd.	Heavy wood. Density at 12% moisture content of 1.080 kg/m³ and green density of 1280 kg/m³	Resistant to fungi, insects, and marine wood borers. Ranging from 10 to 22 years in contact with the soil	External and internal constructions, floors, among others
Garapeira *Apuleia leiocarpa* (Vogel) J. F. Macbr	Heavy wood. Density at 12% moisture content of 880-900 kg/m³ and green density of 1250 kg/m³	Resistant to white- and brown-rot fungi and insects; weatherproof	Joinery, furniture, sleepers, boats, poles, piles, tool handles, among others
Jatobá *Hymenaea courbaril* L.	Heavy wood. Density at 12% moisture content of 890 kg/m³ and green density of 1240 kg/m³	Heart very resistant to fungi and termites. Low resistance to marine borers	Civil construction, luxury furniture, sleepers, truck bodies, implements for trucks, among others
Tauari *Couratari* spp.	Heavy wood. Density at 12% moisture content of 610 kg/m³ and green density of 1100 kg/m³	Tendency to blue stain. It should be used dry and protected from moisture and insects	Civil and naval construction, furniture, curved parts, joinery, domestic utensils, among others

Source: Prepared by the author based on Souza et al. (2002, 2014).

the masonry and wooden construction projects are quite similar (ABNT, 2006).

Although the BUC/m² does not represent the final cost of a construction because it does not include items such as foundations and common area, it was considered as the basis for establishing the FUC/m² for the popular wooden house considering that the two measures are closely related. Both the BUC/m² and the FUC/m² seek to demonstrate the cost of a construction unit from the inputs used in it. Whereas the FUC/m² quantifies foundations, it does not address the cost of leasing equipment, which is considered in the BUC/m². Both can be used as a basis so that producers, consumers, financiers, and the State, as a subsidiary of housing programs for low-income populations, know and apply the minimum cost per square meter of a given construction unit.

According to the ABNT NBR 12721:2006 norm (ABNT, 2006), at least 12 basic items are needed to compose the BUC/m², which comprise the basic set of inputs, and include the cost of equipment, labor, and materials. ABNT lists each input together with the respective coefficient for each specific standard project, demonstrating that, through this coefficient, a series of correlated items is considered in the calculations. The coefficient presents the complete family of each material. When multiplied by the cost of the input family per standard project, the unit cost of a construction can be obtained for any state of the country (CBIC, 2013).

Owing to the lack of norms for a standard wooden house project, physical coefficients are also not available in the academic environment, which motivated the market cost estimate of the inputs needed for construction.

Thus, a mean was calculated for each item from the data provided by timber companies and retailers of construction materials using the Formula 1:

$$\bar{P} = \frac{P_1 + P_2 + P_3 + \ldots + P_{n-1} + P_n}{n} \quad (1)$$

where: $\bar{P}$ = mean prices of suppliers per analyzed item; n = number of suppliers that collaborated in the survey; and $P_1, P_2, P_3, \ldots, P_n$ = prices of items reported by each supplier.

After calculating the mean prices of individual inputs, the Formula 2 was created, which allows combination of all the data analyzed to form the Final Unit Cost of a Popular Wooden House:

$$\frac{FUC}{m^2} = \frac{\bar{P}QM_C + \overline{PQ}OM_{CS} + \bar{P}QEHS_S + \overline{PQ}MO_S}{A} \quad (2)$$

where: $\bar{P}QM_C$ = mean prices of wood suppliers (market); $\overline{PQ}OM_{CS}$ = mean prices of other construction materials (market and SINAPI); $\bar{P}QEHS_S$ = mean prices of electrical, hydraulic and sanitary material (SINAPI); $\overline{PQ}MO_S$ = mean cost of labor (SINAPI); and A = area of a Popular Wooden House = 52 m².

3. RESULTS AND DISCUSSION

After preparation of the spreadsheets containing the individual costs of timber, non-timber inputs, electrical, hydraulic and sanitary material, and labor, it was verified that the monthly variation in the period assessed was approximately 5% between trimesters due to price adjustments of the total inputs, except for labor. Therefore, for discussion, the mean cost was calculated for the period for each set of inputs needed for the project, as presented in Table 3.

Figure 1 shows that the total mean cost of timber was R$ 20,078.07, distributed as a percentage.

The mean total cost for other inputs during the study months was R$ 9,728.48, as presented in Table 4.

Table 5 lists the costs of electric, hydraulic and sanitary materials.

Figure 2 shows the percentage distribution of the final mean costs of non-timber materials described in Annex II of the PWH project, Annex I of Ordinance no. 318/2014 of the Brazilian Ministry of Cities, and

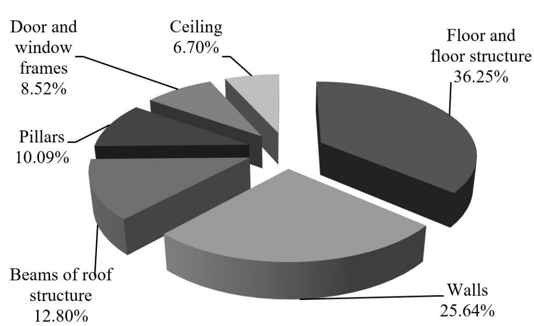

Figure 1. Percentage participation of timber batches for the construction of a Popular Wooden House.

Table 3. Market cost of timber estimated from September 2015 to April 2016.

Type of material	Unit	Quantity	Mean unit value (R$)	Mean total value (R$)
Pillars				**2,025.33**
10 × 10 × 331 cm pillar	piece	3	87.32	261.92
15 × 15 × 356 cm pillar	piece	9	176.24	1,586.15
Pillar complement (15 × 15 × 85 cm)	piece	3	59.09	177.26
Beams of roof structure				**2,569.59**
Slats (1.5 × 5cm)	m	220	1.70	372.90
Rafters (5 × 7 × 435 cm)	piece	10	28.75	287.53
Rafters (5 × 7 × 360 cm)	piece	24	22.79	546.93
Rafters (5 × 7 × 205 cm)	piece	7	13.42	93.93
Purlins (5 × 15 × 205 cm)	piece	2	44.73	89.47
Purlins (5 × 15 × 280 cm)	piece	5	56.19	280.98
Purlins (5 × 15 × 375 cm)	piece	3	80.20	240.58
Purlins (5 × 15 × 481 cm)	piece	1	135.64	135.64
Purlins (5 × 15 × 428 cm)	piece	5	79.87	399.32
Battens for the porch rafters (2 × 10 × 202 cm)	piece	8	15.29	122.31
Walls				**5,147.83**
Panel fixation/purlins (2 × 10 × 360 cm)	piece	10	20.51	205.04
Panel fixation/purlins (2 × 10 × 270 cm)	piece	10	18.33	183.31
Panel fixation/purlins (2 × 10 × 180 cm)	piece	2	15.74	31.49
Panel fixation/purlins (2 × 10 × 90 cm)	piece	4	6.33	25.45
Panel fixation/purlins (5 × 5 × 90 cm)	piece	2	5.74	11.48
Wood-joint or panel fixation/pillars (2 × 4 × 255cm)	m	92	4.12	378.73
Wood-joint or panel fixation/panel (2 × 7 × 255 cm)	m	118	6.56	773.88
Doorstop (5 × 8 × 255 cm)	piece	8	18.76	150.07
Doorstop (5 × 8 × 83 cm)	piece	4	7.14	28.55
Wood board separators (2 × 2 × 15 cm)	piece	36	0.84	30.00
Fixing batten (2 × 10 × 85 cm)	piece	4	4.07	16.27
Lining boards (2 × 15 × 83 cm)	piece	459	5.58	2,560.67
Window/door shutters (1 × 8 × 83 cm)	piece	63	0.55	34.86
Window/door shutters (1.5 × 8 × 76 cm)	piece	36	0.64	22.92
Panel support (5 × 5 × 255 cm)	piece	14	5.81	81.36
Slats or shutters of the gables (2 × 15 × 590 cm)	piece	16	16.90	270.40
Slats or shutters of the gables (2 × 15 × 108.15 cm)	piece	4	4.42	17.69
Slats or shutters of the gables (2 × 15 × 135.8 cm)	piece	4	5.86	23.44
Slats or shutters of the gables (2 × 15 × 161.5 cm)	piece	4	5.29	21.15
Slats or shutters of the gables (2 × 15 × 188.15 cm)	piece	4	5.56	22.23
Slats or shutters of the gables (2 × 15 × 214.8 cm)	piece	4	6.65	26.60
Slats or shutters of the gables s (2 × 15 × 241.5 cm)	piece	4	6.92	27.68
Slats or shutters of the gables (2 × 15 × 268.15 cm)	piece	4	8.36	33.43
Slats or shutters of the gables (2 × 15 × 294.8 cm)	piece	4	8.62	34.47
Slats or shutters of the gables (2 × 15 × 282 cm)	piece	8	8.49	67.89
Slats or shutters of the gables (2 × 15 × 292.5 cm)	piece	8	8.60	68.77
Door and window frames				**1,710.79**
Flat part (5 × 8 × 83 cm)	piece	4	8.11	32.43
Frame (5 × 8 × 109.5 cm)	piece	14	9.62	134.63
Frame (5 × 8 × 83 cm)	piece	14	8.40	117.60
Shutter side (2 × 8 × 36 cm)	piece	8	2.18	17.37

Source: Prepared by the author based on Annex II of the Popular Wooden House Project of Melo et al. (2002).

Table 3. Continued...

Type of material	Unit	Quantity	Mean unit value (R$)	Mean total value (R$)
Panel batten (5 × 5 × 83 cm)	piece	14	4.67	65.33
Panel batten (5 × 8 × 83 cm)	piece	54	6.94	374.85
Panel support (5 × 5 × 255 cm)	piece	54	13.30	717.98
Board (2 × 15 × 83 cm)	piece	42	5.97	250.60
Ceiling				**1,345.24**
Joist support (3 × 3 × 360 cm)	piece	7	10.83	75.79
Joist support (3 × 3 × 177.5 cm)	piece	1	3.12	3.12
Ceiling fixing bar (5 × 6 × 280 cm)	piece	29	15.77	457.43
Ceiling fixing bar (5 × 6 × 250 cm)	piece	3	14.90	44.69
Ceiling fixing bar (5 × 6 × 100 cm)	piece	2	5.97	11.93
Ceiling boards (1 × 10 cm)	m^2	50	9.55	477.28
Ceiling skirting	m	55	5.00	275.00
Floor and floor structure				**7,279.29**
Floor sleeper (5 × 15 × 270 cm)	piece	5	49.68	248.36
Floor sleeper (5 × 15 × 140 cm)	piece	2	33.78	67.55
Floor sleeper (5 × 15 × 360 cm)	piece	5	64.42	322.08
Floor sleeper (5 × 15 × 190 cm)	piece	1	39.39	39.39
Floor sleeper (5 × 15 × 247.5 cm)	piece	1	47.76	47.76
Bar support (5 × 7 × 352 cm)	piece	7	26.11	182.76
Bar support (5 × 7 × 132 cm)	piece	2	8.99	17.98
Bar support (5 × 7 ×175 cm)	piece	2	13.43	26.86
Bar support (5 × 7 × 233.5cm)	piece	1	16.78	16.78
Longboard bar support (5 × 11 × 280 cm)	piece	27	37.99	1,025.78
Longboard bar support (5 × 11 × 100 cm)	piece	2	13.56	27.12
Longboard bar support (5 × 11 × 75 cm)	piece	6	11.64	69.83
Floor sleeper supports (4 × 15 × 42.5 cm)	piece	23	21.38	491.63
Floor sleeper supports (4 × 10 × 42.5 cm)	piece	04	8.66	34.64
Lining floor board (2 × 15 cm)	m^2	63	59.85	3,770.55
5 cm wall skirting board	m	45	6.50	292.50
Stairs (5 × 18 × 110 cm)	unit	04	35.48	141.88
Stairs (3 × 30 × 152 cm)	unit	02	45.56	91.11
Stairs (3 × 30 × 82 cm)	unit	02	21.72	43.43
Porch body guard (5 × 11 × 400 cm)	piece	07	31.50	220.50
Porch body guard (5 × 11 × 300 cm)	piece	04	25.20	100.80
Total cost of wood				**20,078.07**

Source: Prepared by the author based on Annex II of the Popular Wooden House Project of Melo et al. (2002).

the cost of electrical, hydraulic and sanitary materials, after attainment of the respective projects (Brasil, 2014).

The final cost of labor required to provide construction services was R$ 16,032.77. The number of man-hours for these professionals was calculated following guidance of the architect of the PWH project and the civil engineer who designed the complementary projects: electric, hydraulic and sanitary, as shown in Table 6.

Figure 3 depicts the quantitative percentage participation in the composition of the Final Unit Cost of a wooden house with all the inputs indispensable to its construction. The final unit cost for the months analyzed was R$ 934.52/m^2, totaling R$ 48,595.04.

The Construction Industry Union of the State of Acre (SINDUSCON-AC) does not survey the BUC/m^2 for its constructions; therefore, data on the BUC/m^2 of a two-bedroom R1B house disclosed by the of Industry and Commerce Union of the State of Amazonas (SINDUSCON-AM) was used to compare with the FUC/m^2 composed for popular wooden house, as shown in Table 7 (CBIC, 2016, 2019a).

However, in order to compare the value of the BUC/m^2 disclosed by the SINDUSCON-AM with what would be a similar BUC/m^2 for the same construction in the state of Acre, a BUC/m^2 was composed for that state using the R1B project: low-cost, single-family

Table 4. Market cost of other construction materials estimated at retailers from September 2015 to April 2016.

Type of material	Unit	Quantity	Mean unit value (R$)	Mean total value (R$)
Doors and windows				**2,153.31**
Flush wood door for painting 80 × 210 × 3.5 cm	unit	2	117.62	235.23
Flush plywood door for painting 80 × 210 × 3.5cm	unit	2	185.47	370.94
Flush wood door for painting 60 × 210 × 3.5 cm	unit	1	110.30	110.30
Wooden pivoting window, without shutter, with trim	unit	7	150.67	1,054.66
Wooden swing window, regional 3a type	unit	1	94.07	94.07
Built-in door lock for external door, door handle, and metal mirror	unit	2	31.94	63.88
Built-in door lock for internal door, popular line	unit	1	24.83	24.83
Built-in door lock for bathroom door, popular line	unit	1	24.16	24.16
Steel and/or iron hinge, 3” × 2 â½”, 1.2 to 1.8 mm thick	unit	26	6.74	175.24
Roof				**4,345.17**
Half-round ceramic roof tile, 47 cm, coverage 26 pieces/m^2	m	2360	1.78	4,192.93
Ceramic roof tile ridge, 41 cm, coverage 3 pieces/m	piece	30	5.09	152.24
Masonry and foundation				**2,136.93**
8-hole ceramic block, de 9 × 19 × 19 cm	unit	660	0.55	363.00
Portland composite cement, CP II-32 (50 kg bag)	unit	18	34.98	629.70
Crushed stone no. 1 (9.5 to 19 mm), quarry supplier	m^3	2	228.44	456.88
Crushed stone no. 2 (19 to 38 mm), quarry supplier	m^3	3	225.09	675.26
Medium sand, deposit supplier	m^3	0.3	40.31	12.09
Painting				**806.50**
Premium matte white acrylic paint	gal	6	65.05	390.28
Termiticide, Pentox®	l	5	29.68	148.10
Bright synthetic varnish	l	7.2	17.98	129.43
Turpentine diluent solvent	l	5	10.30	51.50
Paint roller	unit	3	25.15	75.44
Sandpaper for wall or wood, no. 120	unit	5	0.55	2.75
Cotton waste	kg	1	9.00	9.00
Screws, bolts, nuts, nails and hardware				**306.57**
French head galvanized bolt 3/8” (9.5 × 130 mm) nut/washer	unit	49	1.36	66.64
French head galvanized bolt 3/8” (9.5 × 180 mm) nut/washer	unit	19	1.76	33.44
Slotted screw 5.5 × 75 mm	unit	48	2.01	96.48
S10 bushing	unit	08	0.39	3.12
Nail 15 × 15	kg	03	10.71	31.13
Nail 17 × 21	kg	02	11.42	22.84
Nail 18 × 30	kg	04	13.23	52.92
Total cost of other construction materials				**9,728.48**

Source: Prepared by the author based on Annex II of the Popular Wooden House Project of Melo et al. (2002).

house comprising one floor with two bedrooms, living room, bathroom, kitchen, and wash area, in 51.94 m^2 (ABNT, 2006).

Table 8 shows the cost of materials, labor, administrative expenses, and equipment, regulated by the norm of batch of inputs, collected using the SINAPI in Rio Branco, Acre state, from February to April 2016 and September to November 2016.

The cost per square meter for the construction of low-cost dwellings in the state of Amazonas is similar to that in Rio Branco, Acre state, with an approximate difference of R$ 45.00/m^2.

Owing to the absence of studies addressing wooden constructions exclusively, other types of popular construction intended to the low-income population were taken as reference as a solution to reduce the housing deficit in localities where this theme is studied.

In Brazilian constructions, there is predominance of the use of masonry, whether in ceramic or concrete brick, disregarding the possibility of building a good, single-family dwelling with affordable cost and thermal comfort for the low-income population. Prefabricated wooden houses constructed with wood from the Amazon forest are a viable alternative; because of their thin walls (3-6 cm thick), they adapt to regions with warmer climate (Souza, 2013).

In analysis of the constructive potential of the Steel Frame and Wood Frame light systems in the production of low-cost housing, in recent years, an industrial park has been implemented in Brazil to produce components of these systems, particularly Steel Frame, with the creation of manuals, financing of technology, dissemination, and training of professionals. The following aspects are considered relevant: lightness, constructive speed, and final quality of the construction – superior to the conventional masonry constructions (Meirelles et al., 2012).

Table 5. Market cost of electric, hydraulic and sanitary materials estimated using the SINAPI* from September 2015 to April 2016.

SINAPI code	Type of material/ Installation	Total cost (R$)
Various	Hydraulic installations	1,133.99*
Various	Sanitary installations	909.42*
Various	Electrical installations	712.38*
	Total cost of materials	**2,755.79**

*SINAPI = National System of Costs Survey and Indexes of Construction (Brasil, 2019).

According to the studies by Grigoletti et al. (2008), construction of low-cost housing is a permanent challenge in Brazil because, whereas costs must be

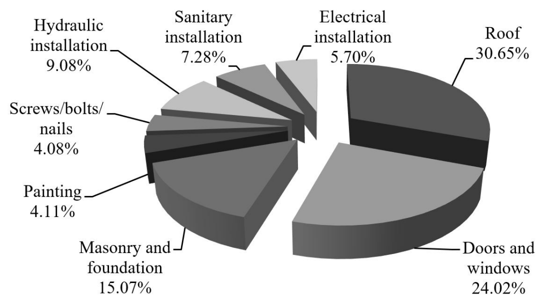

Figure 2. Percentage participation of other construction materials in the cost composition of a Popular Wooden House.

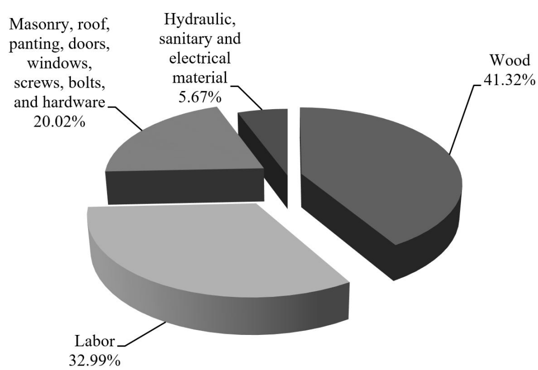

Figure 3. Percentage participation in the Final Unit Cost (FUC/m^2) of the Popular Wooden House.

Table 6. Quantitative labor cost for the construction of a Popular Wooden House.

Quantity	Professional	Man-hours/ day	Total hours/ professional	Cost per hour (R$)	Total cost/ professional (R$)
2	Mason	8 x 8	128	13.97	1,787.73
1	Hod carrier	8 x 8	64	10.17	650.67
4	Carpenter	8 x 15	480	13.97	6,704.00
2	Carpenter's assistant	8 x 15	240	10.49	2,517.60
1	Roofer	8 x 5	40	12.08	483.07
1	Painter	8 x 8	64	13.97	893.97
1	Painter's assistant	8 x 8	64	10.49	671.36
1	Plumber	8 x 8	64	13.97	893.97
1	Plumber's assistant	8 x 8	64	10.49	671.36
1	Electrician	8 x 4	32	13.97	446.93
1	Electrician's assistant	8 x 8	32	9.70	310.40
Total cost of labor					**16,032.77**

Source: Prepared by the author based on the professional market survey data.

Table 7. Comparison of costs in R$/m² between wooden and masonry houses.

Month and year	52 m² Popular Wooden House in Rio Branco, Acre state		51.94 m² Conventional Masonry House in Amazonas state		Difference in %
	FUC[1]/m²	R$	BUC[2]/m²	R$	
Sep 2015	917.21	47,694.92	1,291.51	67,081.03	28.98
Oct 2015	914.29	47,543.08	1,293.93	67,206.72	29.34
Nov 2015	918.83	47,779.16	1,296.86	67,358.91	29.15
Feb 2016	961.07	49,975.64	1,300.69	67,557.84	26.11
Mar 2016	950.88	49,445.76	1,302.23	67,637.83	26.98
Apr 2016	944.84	49,131.68	1,308.71	67,974.40	27.80
Mean	**934.52**	**48,595.04**	**1,298.98**	**67,469.45**	**28.06**

[1]FUC = Final Unit Cost; [2]BUC = Basic Unit Cost. Source: Prepared by the author based on data disclosed by at the BUC website (CBIC 2016, 2019a).

kept between US$ 3000-4000, the housing deficit is excessively high and the financial resources for housing programs are limited. The Alvorada House project prototype was built in Porto Alegre, mainly composed of cement-based brick, with wooden doors, windows, and arbor/porch. The construction was completed in 2003 and has undergone several evaluations regarding the sustainable strategies employed.

Considering that the study of Grigoletti et al. (2008) addressed the architectural aspects of a popular house, the final cost of construction for April 2016 (exchange rate on April 15, 2016 = US$ 1.00/R$ 3.52) would be R$ 14,108.00 for a 48 m² house (FinanceOne, 2017).

The study by Grigoletti et al. (2008) did not include estimate of construction costs standardized by the ABNT, and the amount reported is considerably lower than the actual market prices for housing construction.

Analysis of several construction technologies using sustainability indicators and final costs of single-family housing in Zurich, Switzerland, demonstrated that construction costs are a determining factor for the success and implementation of a constructive technology in the market. Affordable housing is defined as that with cost up to US$ 200.00/m², including direct and indirect costs and all details associated with finishing (Wallbaum et al., 2012).

Along this study, considering a 52 m² house as standard, its final cost would be US$ 10,400.00, which for April 2016 (exchange rate on April 15, 2016 = US$ 1.00/R$ 3.52) would be of R$ 36,680.80 (FinanceOne, 2017).

A project using Fiber Reinforced Cement Compound (FRCC) was developed for the construction of popular dwellings to serve the low-income populations of the Pacific Islands. The project consists of a modular pre-molded system, designed to reduce unit costs and provide housing built through self-construction, using the local manpower of the homeowners, which does not require specialized qualification, only technical assistance from manufacturing to final assembly of the construction (Rockwood et al., 2015).

In Hong Kong, USA, public housing became a political priority as of 1953, after a fire had left approximately 53,000 people homeless. In 2003, with the great outbreak of respiratory diseases caused by the insalubrity conditions of the public houses (PH), a process to modernize the dwellings aiming to improve the sanitary and environmental conditions of the city was initiated. In the same year, the public rental housing program (PRH) was launched and the proposal is to house 3.5 million people in approximately 271 thousand PRHs by 2023 (Deng et al., 2016).

In Italy, social housing (SH) has been on the government's agenda of housing programs for decades, especially after the World War II. As of the 1980s, the Italian housing issue has been neglected, leaving the task of providing affordable housing to cooperative enterprises, favoring an increase in private property rate. In the past years, with the international real estate crisis, the public investments aimed at that sector of the society have been minimal. Since 2010, public-private partnerships (PPP) have been initiated for investments in the country's housing sector, encouraged by subsidies to funders (Copiello, 2016).

It is worth discussing the comparison between the cost of a residential unit developed in Rio Branco by

Table 8. Calculation of BUC[1]/m² for an R1B house from the physical coefficients of inputs in Rio Branco, Acre state.

SINAPI Code	Type of material	Unit	Quantity	Physical coefficient	Mean Sep 2015 to Apr 2016		BUC[1]/m²
					Unit cost (R$)	Total cost (Rs)	
Materials					**769.14**	**39,949.29**	**769.14**
1345	Veneered plywood plank 2.44 × 1.22 m, 18 mm thick	m²	79.14	1.524	31.71	2,509.56	48.32
34	Steel ca-50, 10.0 mm, rebar	kg	949.23	18.276	4.77	4,527.83	87.17
14041	Conventional mixed concrete c10 resistance, with 1 and 2 gravel, slump = 80 mm +/–10 mm (NBR 8953) (ABNT, 2015).	m³	13.59	0.262	540.38	7,342.13	141.36
1379	Composite Portland cement CP II-32	kg	2,929.35	56.399	0.68	1,991.96	38.35
370	Medium sand	m³	8.97	0.173	39.98	358.48	6.90
7271	8-hole ceramic block 9 × 19 × 19 cm	unit	3,042.58	58.579	0.60	1,825.55	35.15
7207	Corrugated asbestos cement roof tile 6 mm thick, 2.44 × 1.10 m	m²	148.49	2.859	53.36	7,923.44	152.55
5020	Hollow-core wood door 60 × 210 × 3.5 cm	unit	5.86	0.113	175.39	1,028.22	19.80
11183	Steel swing window with stop and frame, 100 × 100 cm	unit	12.46	0.240	273.30	3,404.58	65.55
3093	Built-in door lock, Gorge type (large key) 55 mm	unit	6.05	0.116	58.21	352.11	6.78
1297	Glazed ceramic floor tile, PEI ≥ 3, up to 2025 cm²	m²	97.97	1.886	17.37	1,701.80	32.76
540	Cultured marble countertop with 1 washbowl, 200 × 60 cm	unit	0.37	0.007	376.20	137.95	2.66
4812	Ceiling plasterboard, 60 × 60 cm, 12 mm thick	m²	128.44	2.473	10.50	1,348.59	25,96
10492	4 mm colorless plain glass	m²	6.86	0.132	133.33	914.05	17.60
35691	White standard PVA latex paint	l	103.84	1.999	12.25	1,272.08	24.49
517	Anionic asphalt emulsion	kg	64.11	1.234	4.89	313.51	6.04
944	Rigid insulated wire, PVC 450/750 v, 4.0 mm²	m	809.71	15.589	1.56	1,263.14	24.32
2373	NEMA 3-pole circuit breaker 60-100 A	unit	4.38	0.084	72.16	316.26	6.09
10420	White porcelain toilet vase	unit	2.95	0.057	105.33	310.74	5.98
11752	Forged brass pressure water register, 1/2”	unit	9.65	0.186	11.77	113.52	2.19
20073	PVC tube, R series, dn 150 mm	m	27.17	0.523	36.58	993.80	19.13
Labor					**466.85**	**24,248.41**	**466.85**
4750	Mason	h	1,420.40	27.347	13.97	19,842.94	382.04
6111	Hod carrier	h	513.46	9.886	8.58	4,405.47	84.82
Administrative expenses					**108.54**	**5,637.58**	**108.54**
2706	Junior civil construction engineer	h	85.89	1.654	65.64	5,637.58	108.54
Equipment					**0.43**	**22.50**	**0.43**
10531	320 l concrete mixer, 3-phase electric motor, 3 HP, 1.54 h mechanical loading (leased)	hour/day	15.10	0.291	1.49	22.50	0.43
Total					**1,344.97**	**69,857.79**	**1,344.97**

[1]BUC = Basic Unit Cost. Source: Prepared by the author based on the ABNT NBR 12721:2006 (ABNT, 2006) norm, with values collected at the SINAPI (Brasil, 2019), with tax.

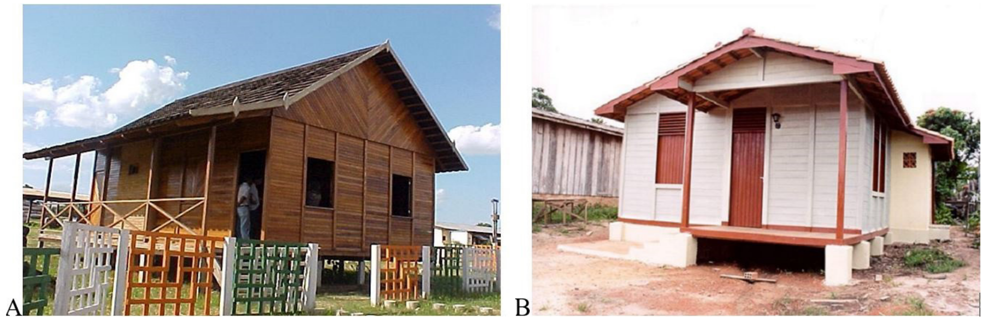

Figure 4. (A) Picture of the Citizen Housing Project prototype developed by FUNTAC (2003); (B) Picture of a Popular Wooden House taken in Pimenta Bueno, Rondônia state (IBAMA; LPF, 2002).

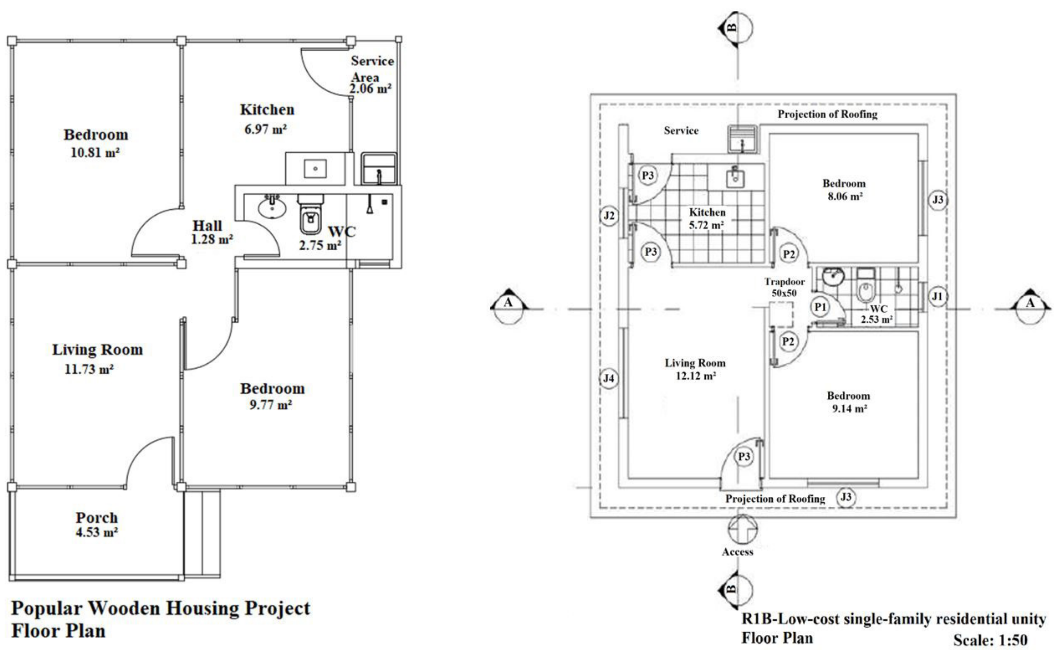

Figure 5. Comparison between the floor plans of the Popular Wooden House and that of conventional popular masonry houses.

the FUNTAC, through the Citizen Housing Project, which was of R$ 431.10/m^2 updated to April 2016 according to the National Civil Construction Index (INCC) and that of the FUC/m^2 of a Popular Wooden House, which was of R$ 934.52/m^2 on average in the period studied. Figure 4 illustrates the two constructions (CBIC, 2013, 2019b).

The final cost of the Citizen Housing Project was composed without considering the cost of labor, roof tiles, hardware, and other materials that were detailed in the PWH project, which justifies the difference observed, because the cost of materials and labor in popular construction exceeds 90% of the total cost.

Ahead, in Figure 5, are the floor plans of the Popular Wooden House originating from the study project and the conventional masonry house used by ABNT. It can be observed that the construction proposals for the Popular Wooden Houses and those regulated by ABNT are similar, differing in the type of material used and the final cost of construction.

4. CONCLUSION

The final construction cost of a single-family dwelling in Brazil, calculated through the application of the BUC/m^2 methodology, is quite high; however, the

Popular Wooden Housing (PWH) project is viable and feasible aiming insertion in the National Rural Housing Program (HRHP) if the final cost of construction is considered, which was 28.06% less costly than that of conventional masonry houses.

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