The housing in recycled container as an alternative to social housing: A comparative cost and productivity

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ABSTRACT: In Brazil, social housing are generally built with traditional building techniques, which abdicates the technologies available in the market. Industrialized systems enable productivity gains, lean construction and optimization of the construction site. In this context, the Container System is presented as sustainable, recyclable and rapid delivery, favoring even service in disaster situations. This study aims to study housing in recycled container as a possibility for social housing, assessing the competitive potential cost and productivity of this system compared to PVC Concrete System. This research is classified as descriptive and exploratory, included in its methodology the following: literature review; identification of industrialized building systems deployed in the State of Espírito Santo; survey to municipalities and construction companies responsible for innovative systems; system selection to be compared to the Container System as incidence and geographical proximity; characterization of recycled container and PVC Concrete System; analysis of the feasibility and basic project housing development in containers; cost comparison later and productivity between systems previously characterized. The study Container System seeks to identify positive applicability in social housing, highlighting technical and cost advantages. The possible development of this system will bring an important advance in building techniques used and will contribute to the recycling of obsolete discards the current nautical market.

Keywords *housing in container, industrialized construction, social housing, cost and productivity.*

1. INTRODUCTION

Since the construction is the human activity greater impact on the environment, sustainability is essential in the development of same. There are several practical projective proposals to a sustainably correct construction, however, the use of raw materials that contributes to the eco-efficiency of the process is also essential (Motta & Aguilar 2009).

Within this context, the construction of social housing should encourage the adoption of best construction practices and adequate to the peculiarities of each region also contributing to improving the sustainability of the built environment.

As the real estate incentive scenario proposed by Brazilian financial Institution, Caixa Econômica Federal (CEF), in the 70s, the Brazilian government encouraged the installation of industrial construction processes, aimed at addressing the housing problem through the mass production of housing, single and multi-family (Mello 2004). However, in the 80s, there was the extinction of the installed housing programs (Financial System of Housing and National Housing Bank) due to the crisis in the housing system, returning to the traditional construction system (Mello 2004).

Again, from a Federal Government initiative, started in 2009, the Minha Casa, Minha Vida - Residential Lease Fund Resources, in order to reduce the housing deficit through grant funding and/ or social housing (Caixa 2016).

This study aims to add the housing system in containers to other industrial systems approved by the CEF. They propose the use of discarded containers due to lower cost achieved, since returning them empty the countries of origin is more costly than producing new containers (Uittenbroek & Macht 2009). In addition, containers were to deviate from the waste generation works because they are modular elements, creating an effective and no corrective solution, the debris generated in conventional construction processes (Mattosinho & Pionório 2009).

In the State of Espírito Santo, spatial area made for this study are currently being deployed three innovative construction systems: PVC Concrete System, Integrated System in Steel Structure and Mobile Steel System. The cities which are implementing are Cachoeiro de Itapemirim, Linhares and Colatina.

Therefore, the objective is to study the feasibility of housing in recycled containers for social housing, proposing an alternative sustainable construction and fast delivery, as well as assess their competitive potential cost and productivity in relation to PVC Concrete System. That said projects under these systems and same spatial distribution were evaluated for cost per square meter and productivity in man/ hour for each wall type.

2. METHODOLOGY AND STRATEGIES

Assuming an analysis developed under descriptive and exploratory nature, this study developed grounded in relevant literatures, also gathering information collected in technical visits with public and construction agencies. Through these, there was recognition of the housing deficit in the Espírito Santo, and was compiled information on

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industrialized building techniques implemented in this State. All systems studied were approved by CEF for social housing purposes.

Diagnose the implemented technologies were carried out on-site visits. After identifying the embedded industrial systems, it was elected the PVC Concrete System by incidence and geographical proximity of IFES Campus Colatina. Since the proposal in containers for social housing in the State it is innovative, it has developed a basic design of housing unit following the same parameters of other systems, which includes areas of compartments as required by the City of Colatina for social housing.

Later, through market research, from construction companies, manufacturers and marketing of components places settled between the Container System and PVC Concrete System, a comparative cost and productivity, both regarding the execution of walls, which is a large impact item on the total cost of construction.

3. DEFICIT OF HOUSING IN THE ESPÍRITO SANTO

The sum of urban and rural needs of the Espírito Santo (Fig. 1), Brazilian State located in the Southeastern Region, totalizes 66,586 units. In Table 1, are arranged the Regions concerning percentages where industrialized building systems have been implemented and their respective municipalities (Pehab 2030 2013).

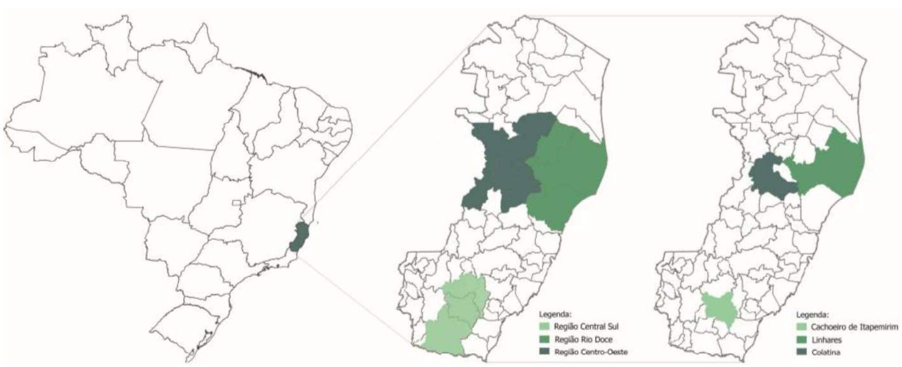

Figure 1. Location of the Espírito Santo and the South Central Region (Cachoeiro de Itapemirim), Rio Doce Region (Linhares) and Midwest Region (Colatina). Source: Brazilian Institute of Geography and Statistics, 2016. Jones dos Santos Neves Institute, 2016.

Table 1 - Housing deficit of the Regions whose municipalities have implemented industrialized systems

City	Industrialized System (Company)	Region	Housing deficit
Cachoeiro de Itapemirim	Integrated System in Steel Structure (Usiminas)	South Central	7,3%
Linhares	PVC Concrete System (Royal)	Rio Doce	10,7%
Colatina	PVC Concrete System (Royal) e Mobile Steel System (Fischer)	Midwest	6,8%

Source: Pehab 2030, 2013.

4. SOCIAL HOUSING ON TECHINICAL INDUSTRIALIZED BUILT

Industrialized building systems implemented in the State of Espírito Santo are listed in Table 2. As the same, it shall see the insertion of PVC Concrete System in two

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municipalities, which is therefore the system designed for cost analysis and productivity as opposed to housing system in containers.

Table 2 - Industrialized building systems in the Espírito Santo

	City	Industrial system
a)	Cachoeiro de Itapemirim	  Integrated System in Steel Structure (Usiminas). Source: Santos, 2014. Pontini, 2016
b)	Linhares	  PVC Concrete System (Royal)
c)	Colatina	  PVC Concrete System (Royal). Source: Arpa, 2014   Mobile Steel System (Fischer)

4.1 PVC Concrete System

Currently in Colatina City there are 1,790 social housing units fractioned into six housing. There is the occurrence of conventional buildings in the first five sets, proposed and built with masonry and hand traditional work (Fortes et al., 2014).

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The sixth set (Table 2c), however, has proposed a constructive industrialized modular PVC profiles filled with concrete. Located in the neighborhood Vicente Soella, the Allotment Nilson Soella III is under construction and will provide 433 housing units.

In Linhares, Municipality which is also deploying PVC Concrete System for social housing, are being built 253 residential units. Located in neighbourhood Santa Cruz, the Allotment is called Conjunto Residencial Jocafe (Table 2b).

Originating in Canada, PVC Concrete System is designed to meet the post disaster deficiencies (floods, storms) quickly. Basically it consists of hollow panels PVC with internal reinforcements embedded vertically between them (tongue and groove) and subsequently filled with lighter fluid concrete (Schmidt 2013).

The hollow interior of the walls of this system facilitates the insertion of armor and necessary piping (hydraulic, electric). Subsequent concreting (only fine aggregates), aims to increase the rigidity of the assembly and enable the mechanical strength by the structure; coatings are the criteria (Schmidt 2013).

According to Royal's Brazil PVC Profiles Industry Ltd., a provider of system Municipalities of Colatina and Linhares, the thickness of 64mm panels filled with structural concrete do not require independent structures such as beams and columns, supporting up to three floors with any kind of slabs. Generally, it uses the foundation radier type (Royal 2016).

It is noteworthy that, according to Schmidt (2013), because it is an industrialized system, the number of activities carried out on site is reduced. For example, building kits arrive cut the work in their final dimensions, ready to be assembled without the need of large inventories. The housing consists of living room, kitchen, bathroom and two bedrooms arranged in about 38 m².

4.2 Container System

The containers are large metal boxes moved on trains or ships in order to behave and conditioning loads, and without maintenance, life for such a need for about 10 years (Milaneze et al., 2012). Idealizing housing using metal modules, Milaneze et al. (2012, p. 618) states that they "reflect a change in company behavior as play a practical role in the lives of individuals, either because of mobility, the price or the constant natural disasters."

Seeking an environmentally friendly, affordable and sustainably productive project, the housing system containers assembles to other industrial systems. As such, this system will assist in agility and completion of the building, will contribute to lower production of waste works and makes use of a well-disposed after completing its life as a freight container, minimizing the continuous piles of containers in cities port (Milaneze et al., 2012).

The modules are produced with physical and geometric properties to be stacked safely during commercial trajectories. Even with this purpose, the modules have an appropriate human scale, with a few modifications can be reached minimum living conditions (Garrido 2011). Thus, for example, it would be feasible to manufacture and stock containers, even if modified for residential use.

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In the marine market, as is defined by Delta Containers (2016), there are two types of dominantly used containers: Dry Container and Reefer Container, both with predefined dimensions, as Tables 3 and 4.

Table 3. Reefer Container Sizing

Refer Container	Internal dimensions			Area
	Length	Width	Height	
20' Standart	5,456 mm	2,294 mm	2,273 mm	12,52 m²
40' Standart	11,590 mm	2,294 mm	2,273 mm	26,59 m²
40' High Cube	11,590 mm	2,294 mm	2,545 mm	26,59 m²

Source: Delta, 2016

Table 4. Dry Container Sizing

Dry Container	Internal dimensions			Area
	Length	Width	Height	
20' Standart	5,898 mm	2,352 mm	2,393 mm	13,87 m²
20' High Cube	5,898 mm	2,287 mm	2,698 mm	13,87 m²
40' Standart	12,032 mm	2,352 mm	2,393 mm	28,30 m²
40' High Cube	12,032 mm	2,352 mm	2,698 mm	28,30 m²

Source: Delta, 2016. ECB, 2016

Model High Cube, whether Reefer or Dry is the best suited for residential purposes, as your right foot is the largest category, with only him over 2.50 meters, minimum ceilings established by NBR 15575: Standard performance (Tello & Ribeiro 2012).

As proposed by Aguirre et al. (2010), a social project in container shows adequate for the purpose of minimizing the housing deficit. For the development of an implementation proposal of this system in Colatina, followed by the current Code of Municipal Works. We used a Dry Container 20' for wet areas due to the municipal legislation accept a lower ceiling height to them. The other compartments are arranged in a Dry 40' High Cube module (Colatina 1996). The building totals approximately 42 m² of floor area.

5. COMPARISON OF CONSTRUCTIVE SYSTEMS INDUSTRIALIZED

The housing construction sector in Brazil resists on opt for industrialized techniques, however, the benefits of streamlined buildings have been highlighted, alongside the growth of the current needs of social housing production (Tab. 5).

Table 5. Comparative broken down between systems

Discrimination	Building systems	
	PVC Concrete System	Container System
Housing types surveyed	Ground floor	Ground floor
Possibility of multi-family building	Yes	Yes
Area family unit	38.0m²	41.56m²
Foundation type Radier	Yes	Yes
Independent structures (beams and pillars)	No	No
Coverage Need	Yes	No
Modulation	Constructive kit	Module
Packing	PVC	Corten steel
Internal coating	No	PVC, OSB or plasterboard
External coating	No	Painting
Lean construction	Yes	Yes
Skilled labor	Yes	Yes

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The distribution of projects of housing units under analysis (Fig. 2), PVC Concrete System and Container System, intentionally follow the same spatial logic. Both were governed as floor area demanded by the CEF in conciliation with the requirements of the City of Colatina for housing social.

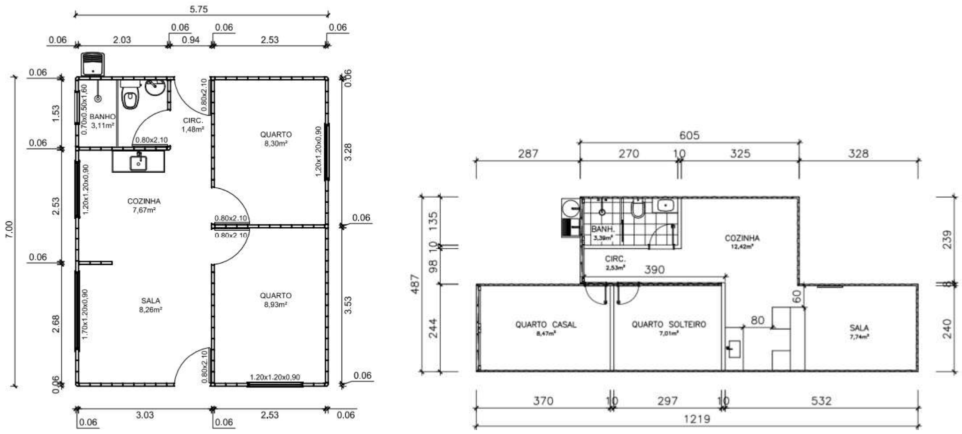

Figure 2. Project constructive kit PVC Concrete System and housing unit in Container System. Source: Arpa, 2014.

5.1 Productivity

As Tables 6 and 7, respectively, are exposed productivity PVC Concrete System and Container System, using the man-hour of the execution stage of the walls, for these are important in the total cost of construction. In them are listed the basic procedures, based on research conducted in State works.

Table 6. PVC Concrete System Productivity

Description	Man-hour/ m^2
Mount hollow wall	0.18
Anchor and put hardware	0.50
Concrete walls	0.25
Cleaning the walls and finishes	0.40
Total man-hour/ m^2	1.33

Source: Domarascki & Fagiani, 2009

Table 7. Container System Productivity

Description	Man-hour/ m^2
Mount the steel structure	0.25
Entering Isosoft Flex in walls	0.06
Closing with plasterboard board	0.29
Paints and finishes	1.55
Total man-hour/ m^2	2.15

Source: Gypsum, 2016. TCPO14, 2012

5.2 Cost

For comparison, this search considers only the closing stages of the coating structure and construction systems, without inserting electrical and hydraulic systems since they are inserted in both systems. Tables 8 and 9 discriminate against the cost of industrial systems analyzed to $1m^2$, adding the values of Social Laws, Benefits and Indirect Costs (BDI) usually applied in the study area.

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Table 8. Composition of the cost per square meter structure and sealing PVC Concrete System

Description	Unit	Consumption	Unit Price (R$)	Total Price (R$)
Thickness 64mm PVC pannel	m^2	1.00	84.71	84.71
Dosed concrete and released fck = 20 MPa	m^3	0.08	279.00	22.32
Steel bar CA 50 Ø10mm	kg	1.50	2.94	4.41
Slatted peroba 5x1.2 cm	m	1.00	3.00	3.00
Nail 18.27"	kg	0.001	8.80	0.01
Total workforce	h	1.33	8.45	11.23
Social laws	127.95%			14.36
Total				140.05
BDI	30%			42.01
			Adopted Unit Price (R$)	182.06

Source: Domarascki & Fagiani, 2009. Sinduscon ES, 2016

Table 9. Composition of the cost per square meter of the Container System structure and sealing

Description	Unit	Consumption	Unit Price (R$)	Total Price (R$)
Structure/ metal seal Container Dry 20 '	m^2	1.00	84.45	84.45
Plasterboard plate	m^2	1.03	20.00	1.54
Isosoft wool Tile Flex IA 75 1.2x25m	m^2	1.05	0.30	0.31
Guide 70 mm	m	0.70	2.82	1.97
Amount 70 mm	m	2.30	2.93	6.73
Screw LA 9.5mm	un	2.00	0.05	0.10
Screw TA 25 mm	un	12.00	0.02	0.24
Grouting mass	kg	0.43	2.22	0.95
Paste	Kg	0.05	5.00	0.25
Latex paint	L	0.17	8.78	1.49
Net preparer	L	0.12	9.29	1.11
Enamel paint for metals	L	0.16	12.00	1.92
Red lead	L	0.12	6.60	0.79
Aguarraz	L	0.03	16.20	0.49
Sandpaper	un	0.50	1.00	0.50
Total workforce	h	2.15	5.55	11.93
Total				114.77
Social laws	127.95%			15.26
Total				130.03
BDI	30%			39.00
			Adopted Unit Price (R$)	169.03

Source: Gypsum, 2016. Sinduscon ES, 2016. TCPO14, 2012

5.3 Comparative assessment between systems

As shown in Table 5, the Container System has characteristics very similar to the PVC Concrete System adopted in the Espírito Santo. As Table 6, there was the largest man-hour productivity per square meter for PVC Concrete System, since the walls are built and completed simultaneously. However, the cost of one square meter of the Container System totaled a lower value in Table 9, indicating this system a viable option for social housing. Still, it sums up the benefits of this, cutting spending on coverage, since the module already has simply cover it as the walls.

Although the PVC Concrete System have higher productivity in the execution of the walls, it is believed that all were considered the existence of coverage container modules

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considerably increase the total productivity of execution, favoring the system's competitiveness.

6. CONCLUSION

The fact that industrial systems be approved by the CEF as social housing alternatives, exemplifies the reopening of the building to non-traditional techniques, which enables the search for innovative processes.

Thus, the Container System has the potential to contribute to reducing the housing deficit in the Espírito Santo, bringing quality housing, rationality, speed of execution, easy expandability of these villas and the possibility of storing them in the long run, as needed. Compared to other systems presented in this research, this system brings a site management more streamlined works, with good final results in terms of cost.

Within this context, we emphasize that the Container System enables ecological sustainable development with values within the market reality. Thus, key items the housing needs would be taken care combined with responsibility for the environment, as they opt for housing in containers helps in reducing the consumption of natural resources and raw materials.

However, there are still no standards or drafts of Brazilian guidelines governing the Container System. The possible approval by the CEF, which is subject to publication of constructive guidelines of this system will bring a major breakthrough in the techniques used and will contribute to the recycling of disposal of the nautical market.

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