

OBSERVING CUSTOMIZATION OF MULTILAYERED BUILDINGS WITH FOCUS ON LEAN CONSTRUCTION

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ABSTRACT

Although the adoption of customization can be a significant differential, it is not easily achieved without a strict management. The customization process of the housing product emerges as an important factor that can add value to the product by considering the requirements of consumers, and this is one of the principles covered by the Lean Construction. This study aims at identifying the offer of customized multilayered buildings in three cities of São Paulo (São Carlos, Mogi das Cruzes e São Paulo) and verifying the interference in the management of the construction site through the application of the Lean principles. Therefore, the methodology chosen was the case study, whose strategy was to apply a questionnaire to six construction companies. The final analysis shows that the companies have found a way of introducing the flexibility in their businesses by planning distinct layouts and different possibilities of alteration. However, only four of them allow the client to modify the internal appearance of the residences. Besides that, even with the restrict knowledge of the Lean concepts in the construction industry, it was observed that all the companies apply the basic tools of this philosophy, albeit in a superficial manner, and have reached significant improvements in the development of their work, enabling them to include the customization in their processes.

KEYWORDS

Lean Construction, customization, value, production planning, product development.

INTRODUCTION

Despite being among the main economic sectors, the construction industry has great difficulty understanding the concept of satisfaction, and then fails to identify exactly what each customer really needs. It is in this scenario of great advances in construction, but still lacking the refinement of operational resources that the use of concepts related to real estate customization process is emerging and being intensified. This strategy has been used as an alternative to achieve competitive advantages, as it seeks to add value to the activities of commercialization of products in order to differentiate the construction company from the other competitors, since it implies the

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possibility of modifying the product during its construction, besides being a way to satisfy the consumer.

THE CUSTOMIZATION OF BUILDINGS

The concept of customization refers in general to the offer of differentiated products without significant increase in costs and time of delivery, that is, a means of obtaining personalized products at competitive prices. Davis (1989) defines customization as the “ability to provide products and services designed individually for each client through process of great agility, flexibility and integration”. According to Stahl (2005), personalizing is not the same as providing a variety of choice but producing in order to meet the individual desires of a consumer.

One of the proposals of customization in construction is to incorporate flexibility in the production process, which can be defined as the freedom to redesign the interior space of a building. Thus, it is understood as initial flexibility the one which allows the client to make choices and adjustments to the physical space related to the first occupation during the construction process (Brandão and Heineck 1998). That initial flexibility is complemented by the continuous flexibility, also known as posterior or functional, which represents the adjustment of the physical space of the housing along the time. Focusing only on the initial flexibility, Brandão and Heineck (1997) classified the construction projects in four groups:

- Group 1: different floor plans are offered for the same project, but with pre-defined locations;
- Group 2: presents alternatives for different rooms or sectors; several layouts are given though none of them is the standard option, or else, it determines the wet area proposing several combinations for the other rooms;
- Group 3: only the perimeter with the positioning of the windows is given and the internal configuration is defined by the client with his/her own architect;
- Group 4: grouping or dismemberments of apartments on the same or different floors can occur.

According to Brandão (2002), the offer of customization is characterized either by the possibility of a planned flexibility related to the proposal of differentiated layouts on the project phase or by the allowed flexibility, in which the standard product to be modified is offered. Because it has an implementation form relatively complex during the construction, Tillmann and Formoso (2008) proposes that the contractors adopt the following strategies of customization in order to facilitate the execution of the required changes:

- Tailored customization: the adoption of this tactics implies the participation of clients in the product design;
- Customized standardization: the standardization is related to the projects, which together with the different components assure the diversity of the product;
- Customization by additional works: the housings are built in a standardized way and customized when delivered;

- Late configuration: associated with the modifications of housing those occur over use, although without major modifications in the living space.

For Fogliatto et al. (2011), there are four main phases in the generation and processing of customization: (1) the development of the products catalogue; (2) the identification of the client's options; (3) the transferring of instructions to the factory, and (4) the transformative manufacturing of the personalized products. For these authors, the success of customization depends on the consumer's needs, the market behavior, the value chain of the sector, the technology, the customization offer, and on the transfer of knowledge to the consumer, to the production and to the suppliers.

Despite the reformulations required and the potential obstacles found to adopt the customization, the diversification of the buildings are being adopted by contractors all over the country, which may be considered an irreversible process. So, it is noticed that the companies willing to adopt the customization must seek well defined solutions and strategies about what will or not be allowed to modify (Rocha et al. 2012) in order to apply it efficiently to their projects without any impairment to the progress of the work.

THE LEAN CONSTRUCTION

Although the adoption of customization can be a significant differential, it is not easily achieved without a strict management. Therefore, the Lean Construction emerges as an approach which seeks to enable the increase of efficiency and the value produced in the activities of conception, design and processing, as well as the minimization or even the elimination of the obstacles to value creation, aiming at the client's satisfaction added to the increase of competitiveness facing companies.

According to Kemmer et al. (2012), the case study carried out in a construction company showed that the customization can be supported by the Lean Construction principles, especially to maintain the efficiency of the process. The transparency principle was adopted for office activities, as in the management of their customization designs and their processing before being delivered to the production area. The production practices were related to principles in order to reduce the uncertainty and increase the output flexibility. The use of the cellular production system, with groups of activities aiming to increase the product flexibility, was also observed. To reduce the part of non-added value, for instance, it was used the system of planning and control which avoids delay in the production line caused by the delay of clients' decisions and delay of definition of delivery procedures of finishing materials at the construction site.

In general, the customization is directly related to the process of value generation because it considers its perception by the individuals referring to the satisfaction of individual desires (Piller 2003); as well as to the increase of flexibility of output of products through the change of their physical characteristics without raising considerably their final cost. It can be noticed then, that the implementation of lean construction in the production process becomes fundamental to the contractors willing to stand out in the market through customization.

METHODOLOGY

The methodology chosen was the case study, whose strategies used to obtain the data were the scheduled visits, the document analysis, direct observation, visual recording and the application of the questionnaire to six contractors in the State of São Paulo. The questionnaire used was based on Araujo Filho (2009), which aimed to identify the customization process of multilayered real estates in the city of Campina Grande, PB. The aim was to understand the consequences and difficulties arising from the adoption of customization.

In the second part of the research, the use of lean construction in the building process was analyzed considering the principles presented by Koskela (1992). In order to do so, it was adapted a questionnaire developed by Kurek et al. (2006), composed of two questions for each of the 11 principles of Lean Construction (LC), identifying those which were more related to the construction site. In the field research the answers to the items in Table 1 were observed. The items evidenced were marked with “yes” (representing the positive aspects) and the answers marked with “no” represented the negative aspects.

Table 1 – Questions to verify the application of the lean concepts

Principle of LC	Question 1	Question 2
1. Reduce of non value-adding activities	Is there storage of materials near the place of use?	Is there decrease of activities in movement, inspection and wait for materials?
2. Increase output value through consideration of customer requirements	Are there the needs of internal and external clients identified?	Is there task planning ensuring customers' requirement in the sequence of activities?
3. Reduce variability	Are there standard procedures for the performing of tasks?	Are there standard procedures to receive the materials?
4.Reduce the cycle time	Is there division of the production cycles?	Is there evidence of elimination of flow activities which are part of a production cycle?
5. Simplify by minimizing the number of steps	Are there used prefabricated components, kits or machines in the production process?	Is there the planning of the production process?
6. Increase output flexibility	Is the construction process allows for quick flexibility of product?	Have in the production teams with polyvalent ability?
7. Increase process transparency	Have in the construction site no visual obstacles such as partitions?	Have in the construction site visual signs, signaling and control charts?
8. Focus control on the complete process	Is there planning and control of production?	Has the company partnership with suppliers?
9. Build continuous improvement into the process	Are performance indicators used to monitor the processes?	Are there procedures to monitor corrective actions and eliminate them with preventive actions?
10. Balance flow improvement with conversion improvement	Are evidenced practices of improvements in flows through the mapping process?	Is there a short-term planning strategy?
11. Benchmark	Does the company know its own processes?	Are the good market practices analyzed and adapted to the reality of the company?

Thus, by the answers obtained, the Principles Indices (PI) was calculated according to Equation 1:

$$PI = \left(\frac{\sum Yes}{\sum Yes + \sum No} \right) \times 100 \quad [\text{Eq. 1}]$$

Where: $\sum Yes$ = sum of affirmative responses;
 $\sum No$ = sum of negative responses.

With the results of each principle, we obtained the Lean Construction Index (LCI), whose value was calculated using the weighted mean of the points obtained by PI, represented by the Equation 2, where ‘p’ is the weighting given by 0.909, as there are eleven principles ($10/11 = 0.909$), providing:

$$LCI = \left(\frac{\sum PI \times p}{\sum p} \right) \quad [\text{Eq. 2}]$$

PRESENTATION OF RESULTS

For a more complete analysis, Table 2 presents the characteristics of companies and enterprises visited. As we can observe, the first three contractors are included in a governmental program, being only companies B and C small businesses. The number of floors and buildings, the total of units and the area of the lot are the most important to be considered from the data collected, because from the layout configuration until the execution of activities during construction, they all must be addressed differently due to the considerable difference in the values obtained. Moreover, it is noticed that the structural system chosen has direct influence on the options of flexibility offered, that is, the structural brickwork restricts the project, hindering the removal of walls.

Table 2: Characteristics of company and enterprises visited

Items	A	B	C	D	E	F
Cities of São Paulo State	São Carlos	São Carlos	São Carlos	Mogi das Cruzes	São Paulo (Capital)	São Carlos
Size of company	Large	Small	Small	Large	Large	Large
Standard of building	Low-cost	Low-cost	Low-cost	High	High	Medium
Floors	5	7	5	20	12	13
Towers	10	1	1	1	6	2
Units per floor	6 or 10	8	4 or 8	1	2	4
Total units	400	56	28	16	120	100
Area of lot	20.369 m ²	1.960 m ²	600 m ²	2.400 m ²	7.200 m ²	52.832 m ²
Constructive system	Structural masonry	Structural masonry	Structural masonry	Reinforced concrete	Reinforced concrete	Structural masonry

Once they are buildings still in construction, the research considered only the initial ways of flexibility offered, not analyzing the possibilities of continuous flexibility in the post occupancy. Thereby, Table 3 demonstrates that they all planned variety of layouts, although only Companies D and E allow further changes different from the ones foreseen initially, to be executed in the housing according to the clients.

Table 3: Types of flexibility initially offered (based on Brandão 2002)

Flexibility	A	B	C	D	E	F
Permitted				X	X	
Planned	X	X	X	X	X	X

In order to exemplify the ways of initial flexibility observed and to facilitate the understanding of classification of enterprises, Table 4 shows the options of planned and permitted layouts in each real estate.

Table 4: Layouts offered in each enterprise

Company	Layout options offered	Alternatives for changes	Limitations
A	Eight	-	Structural and hydraulic walls cannot be altered
B	Five	-	
C	Three	-	
D	Three	The client can make his/her own architecture project	The plumbing walls or the balcony finishing cannot be altered
E	Six	The client can make his/her own architecture project	Fixing the wall containing plumbing systems
F	Three	Option of a third bedroom or an enlarged room, besides a hatchway kitchen wall	No structural walls or plumbing walls can be altered apart from those indicated by the company

For not allowing alterations in structural walls during or after the acquisition of the units, the projects of companies A, B, and C were classified in Group 1, according to Table 5. Despite allowing the removal of a wall, company F is also included in Group 1 since this modification had already been pre-defined by the builder, differently from companies D and E, which even offering different layouts enable the clients to elaborate their own design.

Table 5: Classification of projects (based on Brandão and Heineck 1997)

Classification	A	B	C	D	E	F
Group 1	X	X	X			X
Group 2				X	X	
Group 3						
Group 4						

As for the customization of finishes, companies C and F are the only ones which do not offer it, i.e., no change is made in the course of works. Compared to the other contractors changes are permitted in ceramic tiles, countertops and dividers through the selection of pre-determined kits (companies A, B, and E) as well as through the selection of any model of coating and accessories provided by specific suppliers (company D). Thus, Table 6 indicates the tactics of customization used in each work regarding the internal finishing, emphasizing that as the continuous flexibility, the late configuration was not analyzed.

Table 6: Tactics of customization (based on Tillmann and Formoso 2008)

Tactic of Customization	A	B	C	D	E	F
Tailored customization				X		
Customized standardization	X	X			X	
Customization by additional works						

Regarding the analysis of lean construction implementation, Table 7 provides the results calculated for the eleven principles (PI) and from these, indicates the lean construction indexes (LCI) in percentage equivalent to each of the ventures. The high values obtained by companies A, D, and F are noteworthy, while the others showed lower performance for not having identified the requirements of internal customers in the process, not eliminating the flow of activities which do not add value to the product and for not using performance indicators for the monitoring.

Table 7: Index of Lean Construction (LCI) obtained by each company

Principle/PI	A	B	C	D	E	F
1	100	50	100	100	100	100
2	100	0	50	100	100	100
3	100	100	100	100	100	100
4	100	50	100	100	50	100
5	100	100	100	100	100	100
6	50	50	50	50	50	50
7	100	100	100	100	100	100
8	100	100	100	100	100	100
9	100	50	50	100	100	100
10	100	50	100	100	50	100
11	100	100	100	100	100	100
LCI (%)	95,45	68,18	86,36	95,45	86,36	95,45

The Principle Indices (PI) of lean construction can also be represented by using radar graphs shown in Figure 1-6, which enable the comparison of data provided by table 1 and indicates the concepts to be followed by contractors seeking to combine the lean construction with the strategies of customization. It is observed that the sixth principle, related to the increase of flexibility of the product output was the only one which did not obtain the maximum result in all the surveys, because none of the companies hire polyvalent manpower.

In the analysis of the lean concepts application was noted:

- The tactics for reduction of activities which do not add value, adopted by company D by storing the kit of materials at the place of use (Figure 7);
- The concern with continuous improvement through the use of suppliers' performance indicators by companies A, D and F (Figure 8);
- The increase of value of the generated product by company A when allowing different options (Figure 9);
- The increase of transparency in the process by the exhibition of the performance indicators and the schedule of activities at the building sites of companies A and F (Figure 10).

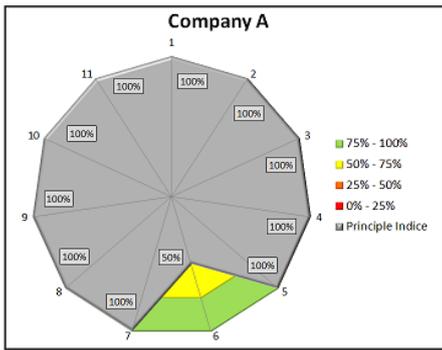


Figure 1 : PI of Company A

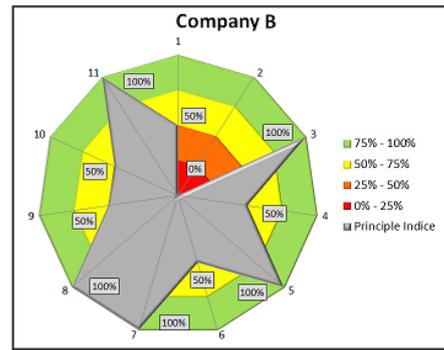


Figure 2: PI of Company B

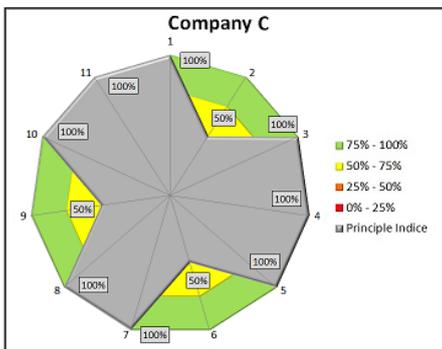


Figure 3: PI of Company C

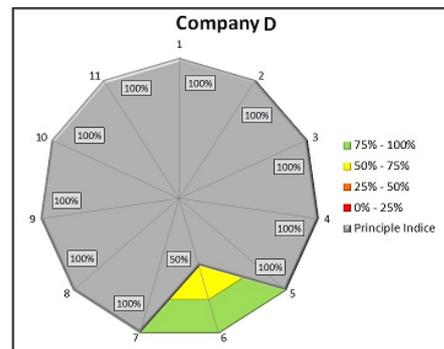


Figure 4: PI of Company D

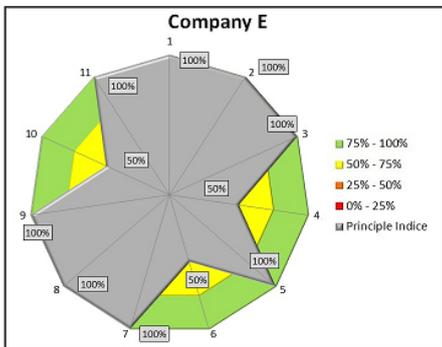


Figure 5: PI of Company E

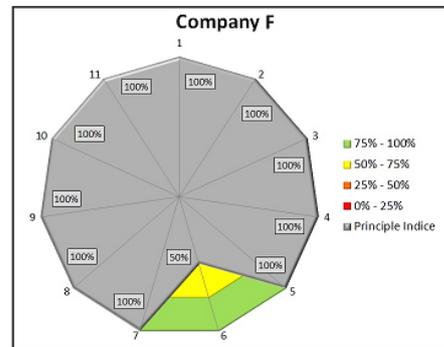


Figure 6: PI of Company F



Figure 7: Storage of the kit of materials



Figure 8: Performance indicators

in the place of use

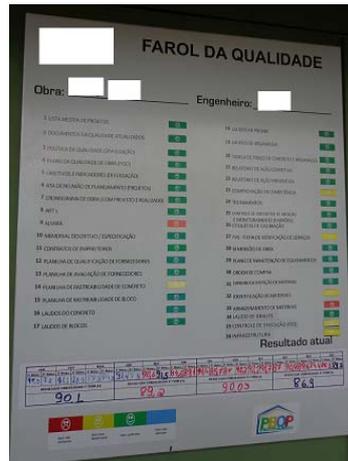


Figure 9: Different options of finishes

Figure 10: Transparency at the building site with the exhibition of the quality indices and the schedule.

Finally, the comparative study among the companies visited proved the use of the customization of buildings strategy associated to the application of lean construction principles at construction sites. However, it is important to note that this analysis that relates to customization with lean construction was exploratory, so it is suggested a more comprehensive assessment of lean principles with the flexibility practices adopted by companies for further studies.

CONCLUSIONS

Based on theoretical studies, it is noticeable that the compliance with the requisites of consumers is one more element to the decision of purchase of the property. Then, there is the difficult task of developing a product based on customization which can meet most of the requests without increasing substantially the final cost. Among these obstacles, it was verified that all the companies have found a way of introducing the flexibility in their projects by providing distinct layouts, besides the fact that four of them (A, B, D and E) enable the modification of finishes during the construction. However, despite this freedom of choice, there are certain limitations in all the projects, varying from the choice of materials to the control of suppliers so that all the requests can be executed in timely manner.

Although the lean concepts are very little known in the market, it was observed either by calculation of LCI or during the visit to the building site that the six companies apply managing tools, mainly those related to the transparency of the process and its global control, reduction of variability and number of parts. Thus, the contractors are achieving significant improvement in the performance of their work which allows them to insert flexibility and the customization. However, one must consider that the lean construction study carried out during the research was quite superficial, since only two basic aspects of each principle were evaluated, which explains the high level of applicability of philosophy. Therefore, it is noticed that the customization offer is a reality in today's market, even in projects of social interest, and it is being adopted as a competitiveness differential by the contractors.

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