Saggin, A. B., Mota, T. R., Brito, F. L., and Mourão, C. A. M. A. (2017). "Standardized Work: Practical Examples in a Brazilian Construction Company." In: *LC3 2017 Volume II – Proceedings of the 25th Annual Conference of the International Group for Lean Construction (IGLC)*, Walsh, K., Sacks, R., Brilakis, I. (eds.), Heraklion, Greece, pp. 713–720. DOI: https://doi.org/10.24928/2017/0128

STANDARDIZED WORK: PRACTICAL EXAMPLES IN A BRAZILIAN CONSTRUCTION COMPANY

Angela de Bortoli Saggin[1], Taynah Ramos Mota[2], Felipe Loiola Brito[3] and Carlos Alexandre M. Amaral Mourão[4]

Abstract: Standardized Work, Heijunka and Kaizen are the basis of the Toyota Production System (TPS) model and provide stability to its pillars. As many tools adapted to Lean Construction, the Standardized Work can also be applied in AEC Industry to increase productivity, reduce waste and define a standardized procedure for the activity.

Recently, the high variability in execution, cost and team member's productivity have caught the attention of the company's construction managers. There is also a high difference between workforce budgeted cost and actual cost, related to a lack of knowledge of the daily routine. The Standardized Work's goal is to identify the roots of these differences, reduce the variability of the main construction work packages, and know the work packages of the Last Planner. The purpose of this article is to present the results of these studies and the improvements identified, such as the increase of the productive time of the teams, the increase of productivity, the reduction of waste, and characterization and standardization of the activities.

This paper contributes to the understanding of Standardized Work and show the application on a construction site. In addition to showing the main results of each work package, the main goal is to exemplify the collection and tabulation of data.

Keywords: Lean construction, standardization, production, job-sequencing, continuous improvement.

1 INTRODUCTION

The Toyota Production System (TPS) was created in Japan between 1984 and 1975 to be a differential in the production of automobiles, offering greater products variety, greater quality, lower cost, and more efficient lead-time.

Standardized Work, Heijunka (continuous flow), and Kaizen (continuous improvement) compose the basis of the TPS system (Ohno, 1997). These three elements look for the complete elimination of waste and sustain the two pillars of the TPS model.

According to TPS, the Lean Philosophy has two pillars: Jidoka (autonomation) and Just-in-Time. The autonomation is the capability of the worker identify and correct abnormalities on the production line. In its basis, the Standardized Work establishes a standard to the execution of an activity and it allows the employee of the production line to have all the information needed to identify and eliminate possible anomalies. It also sustains the pillar Just-in-Time, offering stability to the process so the takt-time is regularly fulfilled (Ohno, 1997).

[1] Civil Engineer, Lean & Green Coordinator of C. Rolim Engenharia Ltda., Brazil, angela@crolim.com.br
[2] Undergraduate Student of Civil Engineering, Intern of C. Rolim Engenharia Ltda., Brazil, taynah@crolim.com.br
[3] Civil Engineer, Technical Manager of C. Rolim Engenharia Ltda., Brazil, felipe@crolim.com.br
[4] Civil Engineer, Technical Director of C. Rolim Engenharia Ltda., Brazil, alexandre@crolim.com.br

The Standardized Work is frequently addressed by the manufacturing industry and it has been extensively researched over the years. However, this subject still has its deficiencies within the AEC Industry, mostly due the high variability within projects and work packages on a construction site. A few case studies from construction contractors were reported, such as Mariz et al (2012), Mariz and Picchi (2013), and Fernandes et al. (2015), however there are no significant results as in manufacturing industry.

It is important to emphasize that the Standardized Work tool is applied to a production cell looking forward to improve productive time and to eliminate waste in order to improve the whole process. Despite of focusing on one stage of the lead time, the Standardized Work should aim for the systematization of the set of production cells through the Value Stream Mapping (VSM) to ensure that one stage does not disturb the other.

To evaluate each work package's execution cycle and the team productivity, each task of the cell's production process is timed and classified by following the definitions established by Carvalho et al (2004):

- Productive Time: the tasks that add value when the activity execution occurs compose the Productive Time. For example, laying the tile adds value to the installation of porcelain or ceramic flooring, and laying the brick adds value to the execution of masonry wall.
- Auxiliary Time: it corresponds to the time spent with tasks that do not add value, but are inherent to the activity. These tasks comprehend the preparation to those that add value, thus they should be optimized. Usually, the Auxiliary Time corresponds to the preparation of materials and tools, organizing and cleaning the workplace, and assembling scaffolding, that is, the set up activities.
- Non-Productive Time (NP Time): it corresponds to the tasks that do not add value and that are not inherent to the activity execution, thus, it corresponds to waste and it should be reduced or eliminated. Usually, the Non-Productive Time corresponds to waiting for material, tools or project information, rework, displacement, and stops for any reason. The Non-Productive Time may correspond to 20-25% of the teams' working hours.

According to Freitas et al. (1994 cited in Carvalho et al., 2004), it is important that the teams have time to rest, such as snack and bathroom breaks, within the daily journey in order to guarantee the accuracy of what was proposed with what normally take place on site. As the construction workers have high workloads within their daily journey, the resting time tend to increase their productivity.

In conclusion, the main goal of this paper is to present the results of the application of the Standardized Work tool in three multifamily residential projects of a construction company located in Fortaleza, Brazil. The company aims to identify the adding value, auxiliary and non-adding value tasks from the main construction work packages and increase productivity by eliminating waste.

The secondary goals of this research are to establish a standard execution process to the main work packages of the Line of Balance (LOB), increase productivity by reducing wastes, improve work safety and workplace conditions, and update the company's planning and budgeting.

2 METHOD

The methodology applied in this research was adapted from the methodology proposed by Mariz and Picchi (2013), and it has five main steps:

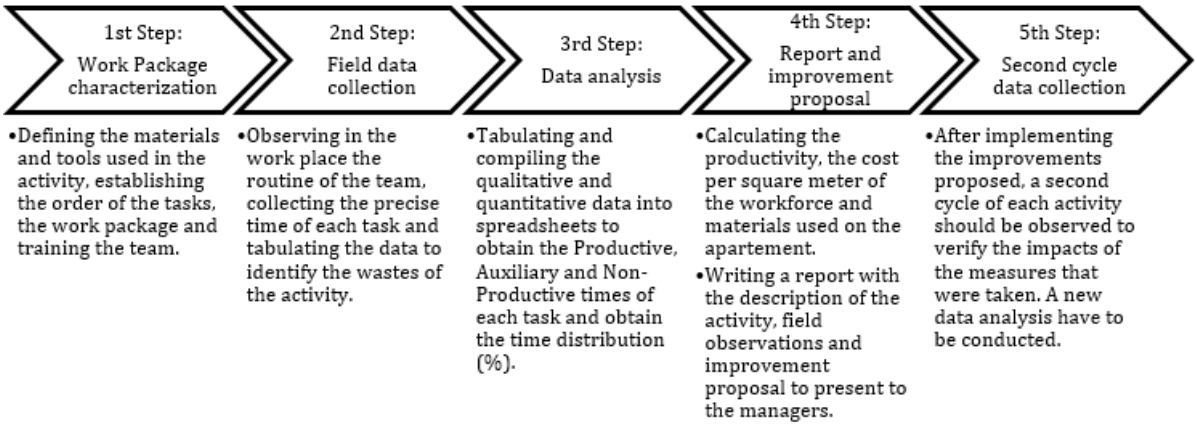


Figure 1: Research methodology

3 CASE STUDY

The proposed improvements are needed to increase productivity and quality, reduce costs and eliminate waste. These improvements may be creating routine cards (with daily goals), acquisition of new tools or features to improve quality, rethinking the inventory plan, retraining the team, etc.

The work packages analysed within this study were waterproofing with acrylic membrane, masonry walls, concrete subfloor (dry and wet areas), porcelain and ceramic floor tile, and gypsum block walls. The data gathering was conducted during the execution of the working packages within the apartments, due the repeatability of the activities.

3.1 The Company

The construction company is located in Fortaleza, Brazil, and it has more than 800,000 m² of constructed area of high standard residential buildings in different neighbourhoods in Fortaleza. The company was founded in 1977 and it started its lean journey in 2004.

Since 2004 it has been developing new tools and practices, and strengthening the relationship with Universities in order to fulfil the Lean Construction gaps and adapt the manufacturing industry tools to the construction sites.

The Standardized Work tool has been applied since 2014 in several construction work packages followed within the Line of Balance (long term planning). A peculiarity of the AEC Industry is that the 'factory' moves to a new site, while the product stays. Because of this characteristic, the study was conducted in three different construction sites of residential projects during distinct construction phases.

3.2 Case Study Development

According to the methodology explained previously, all work packages observed had the minimum information needed to begin the data collection. Which were the tasks sequencing well defined, materials and tools were available at the apartment (shielding

production), and the teams were previously trained to execute each activity. The work package was established in common sense between the teams and work supervisors. This is a very important step thus the improvements of the Standardized Work tool may only be applied if there is an initial standard to be improved.

Each activity was analysed individually through the timing of each cycle activity. The data collected was inserted on a spreadsheet (Table 2), adapted from Mariz and Picchi (2013). For being distinct work packages, the number of team workers may vary, but usually two professional workers (mason, bricklayer, carpenter, etc.) and one hodman (apprentice) compose a team. It is important to observe and collect data from all professional workers, knowing that, in an ideal situation, they should have 100% of their working hours spent with adding value activities. The hodmen (or non-professionals) were not analysed during this case study.

Table 2: Process Study Sheet adapted from Mariz and Picchi (2013)

Hour	Time interval	Executed activities	Comments	Place	Productive, Auxiliary or Non-Productive Time?
13:29:37	00:51,3	Layering brick	2º brick 3ª layer	AP 800	Productive
13:30:28	00:42,5	Stop	Talking	AP 800	Non-Productive
13:31:11	00:49,8	Layering brick	3º brick 3ª layer	AP 800	Productive
13:32:01	00:39,0	Layering brick	4º brick 3ª layer	AP 800	Productive
13:32:40	01:10,2	Stop	Looking for bob	AP 800	Non-Productive
13:33:50	00:14,7	Brick alignment	Verifying alignment	AP 800	Auxiliary

After data tabulation, the activity quantitative and qualitative analysis were conducted, evaluating the time distribution within the main tasks, the productivity, the materials and tools supply during the execution, the ergonomics and shielding production, the need to acquire new tools, and, finally, the activity cost analysis, determining the work and material cost per square meter.

The activities conducted by the work teams are evaluated accordingly to the time distribution of the tasks observed and characterized as Productive, Auxiliary or Non-Productive, as shown on Figure 2.

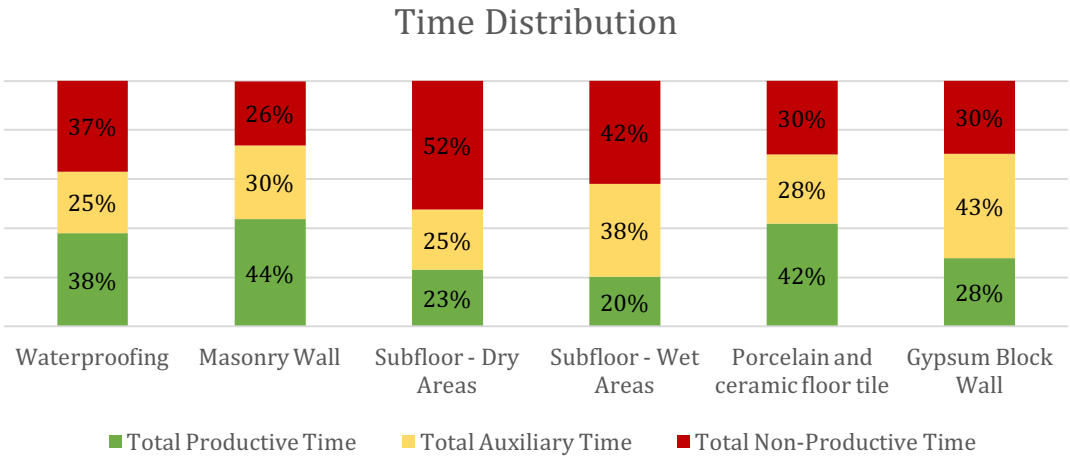


Figure 2: Productive, Auxiliary and Non-Productive time distribution (1st Cycle)

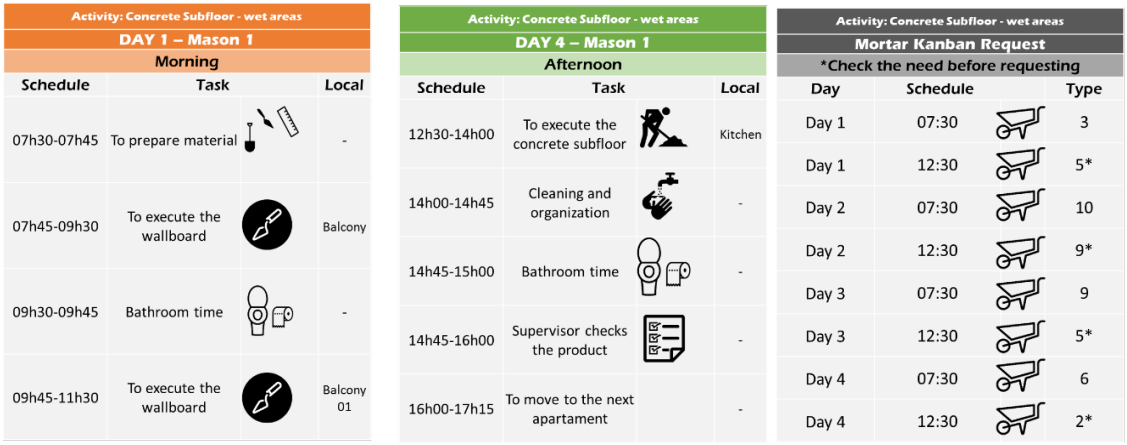
As some of the activities observed had a lead-time that could not be reduced, such as masonry (the lead-time need to be synchronized with the concrete structure rhythm of 8 days/floor due safety and construction process restrictions), the changes and improvement proposed had different goals for each activities.

For example, the improvement proposed to the masonry work package was to redirect the mortar distribution logistics to reduce the Non-Productive Time due waiting for material. Meanwhile, the improvement proposed to the gypsum block work package was to replace the hacksaw with a circular saw to improve the block cutting task and reduce the Auxiliary Time.

Thus, to these situations, the improvements proposed reduce the main wastes of Lean Construction such as displacement, rework, stocking and material waste. The inventory plan is evaluated to verify if it meets the team needs, if the material pallets are obstructing their passage or disturbing the normal activity execution.

One of the results of the Standardized Work is the Routine Card (Figure 3) that helps the team to control its daily tasks and the production rhythm, to program the Mortar Kanban request of each shift and the best sequencing of the activities through the apartment. In addition, the ergonomics of the tasks execution is analysed and it is observed if there are tools that may simplify the work and the sequencing of the activities.

The last step of the Standardized Work tool is the data collection of a second cycle, with the improvements implemented after the first analysis. This step allows evaluating quantitatively and qualitatively the response of the team about the improvements, in case of the application of the Routine Cards, Lean Construction tools training, time cycle reduction, Non-Productive activity elimination, etc.



Activity: Concrete Subfloor - wet areas
DAY 1 – Mason 1
Morning

Schedule	Task	Local
07h30-07h45	To prepare material	-
07h45-09h30	To execute the wallboard	Balcony
09h30-09h45	Bathroom time	-
09h45-11h30	To execute the wallboard	Balcony 01

Activity: Concrete Subfloor - wet areas
DAY 4 – Mason 1
Afternoon

Schedule	Task	Local
12h30-14h00	To execute the concrete subfloor	Kitchen
14h00-14h45	Cleaning and organization	-
14h45-15h00	Bathroom time	-
14h45-16h00	Supervisor checks the product	-
16h00-17h15	To move to the next apartament	-

Activity: Concrete Subfloor - wet areas
Mortar Kanban Request
*Check the need before requesting

Day	Schedule	Type
Day 1	07:30	3
Day 1	12:30	5*
Day 2	07:30	10
Day 2	12:30	9*
Day 3	07:30	9
Day 3	12:30	5*
Day 4	07:30	6
Day 4	12:30	2*

Figure 3: Routine Card of the Concrete Subfloor - Wet Areas Task

As shown on Graphic 4, the Standardized Work intents to reduce Non-Productive time of the work package through the actions previously mentioned. During the first cycle of Porcelain and ceramic floor tile's team, it was observed that the team spent too much time with Non-Productive tasks, because the hodman waited the team run out of mortar and tiles before replenishing. In addition, the tile boxes were misplaced within the floor plan, thus the team needed to move them several time. After stablishing the team daily routine, the Routine Cards were presented to the team and each member's responsibilities and tasks within the activity execution were clarified. During the second cycle it was observed that the Productive Time increased from 42% to 65% and the Non-Productive time reduced from 30% to 13%.

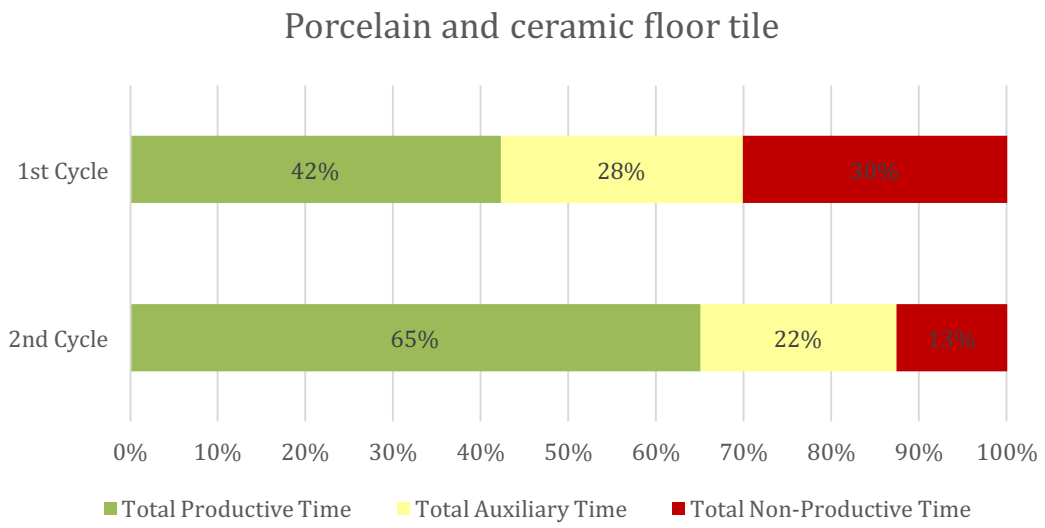


Figure 4: Comparison of time distribution for two observations of Porcelain and ceramic floor tile

After the data analysis, the Standardized Work report is presented to the Construction Site Management team in order to implement the improvements proposed.

4 Results

The results of this case study can be summarized to the work packages characterization and the cost study to update the budget database. This type of record promote the continuous improvement for the next projects, once the Standardized Work Reports were compiled into a collection distributed to all Construction Sites Management Teams and to the Project Management Team (responsible for elaboration of each projects Line of Balance and Construction Budget).

The main results of the six activities mentioned previously were summarized on Table 3. It is important to notice that, the company's goals are keeping the Non-Productive Time within 20-25%, the Auxiliary Time within 15-20% and the Productive Time within 60%.

Table 3: Case Study Results (part 1)

Activity	Results	Indicators
Waterproofing with acrylic membrane (1 mason / 1 hodman)	It was observed that the workers did not have a proper place to store their tools, thus to reduce displacement, a toolbox was made. In addition, two small stools were built to improve their posture while executing some of the tasks. Finally, the team routine was stablished and registered on the Routine Cards.	NP Time: 24% 16,04m²/day/person

Table 3: Case Study Results (part 2)

Activity	Results	Indicators
Masonry wall (2 mason / 1 hodman)	During the first cycle, it was observed that the team was not using the kanban for mortar properly, resulting in constant waiting for mortar, increased by the high demand for the rack lift for transportation of concrete. After a new training about the Kanban and rethinking materials flow within the construction site, the stops reduced from 25% (1st cycle) to 15% (2nd cycle). The productivity has increased 20% and there was a 25% difference between the workforce budgeted cost and real cost.	1st Cycle NP Time: 26% 11,84m²/day/person 2nd Cycle NP Time: 20% 14,20m²/day/person
Concrete Subfloor - dry areas (bedroom and living room). (2 mason / 1 hodman)	The stops, related to waiting for mortar, corresponded to 42% of the time for dry areas. The second cycle was not observed, but the improvements represented a 25% increase on productivity. The concrete subfloor for dry areas had a real cost 37% higher than the budget due a greater material consumption (the budget considered a subfloor thickness of 3 cm but the real thickness is at least 7 cm).	NP Time: 27% 30,19m²/day/person
Concrete Subfloor - wet areas (bathroom, kitchen and balcony). (2 mason / 1 hodman)	The stops, related to waiting for mortar, corresponded to 52% of the time for wet areas. A Routine Card determining when to place the kanban for mortar and the volume of mortar needed was delivered to the team. The second cycle was not observed, but the improvements represented a 10% increase on productivity on wet areas	NP Time: 45% 15,82m²/day/person
Gypsum Block Wall (1 mason)	The second cycle was not observed, but the improvements proposed will be applied on the next project. It was noticed that the workforce budgeted cost is 40% higher than the real cost, while material cost show no important difference. The Routine Cards for the next project predict a 25% decrease on Non-Productive Time (from 28% to 21%) and an increase of the Productive Time from 27% to 42%, by reducing stops and displacement. The productivity is expected to increase 15%.	NP Time: 28% 25,80m²/day/person

5 Research Findings and Conclusion

The Standardized Work Tool has been one of the main Lean Construction Initiatives within the company activities since 2014. The activities evaluated have achieved expressive results, both within a quantitative level as well as within a qualitative level.

The main benefits were reducing Non-Productive and Auxiliary Times, increasing productivity and reviewing the company's budget database, readdressing teams to tasks

that suited their characteristics, improving the work place safety and quality, and giving the team the opportunity to participate on the improvement proposal, creating value for the internal costumer.

It was observed that the team productivities have increased within 15-20% through elimination of Non-Productive activities and reduction of time spent on Auxiliary activities. In addition, the creation of a job sequencing through Routine Cards reduced the work variability and improved its productivity.

The Standardized Work results also showed that the team sizing methodology should be reviewed in order to reduce the idle work force, as well as the man work cost budget methodology should be revaluated.

The most important characteristic of the Standardized Work and job sequencing is that it can be continuously replicated in other activities and different construction types. In addition, all the results are compiled in a report, which is available to the company's and construction site's managers. Thus, the next steps within the company are updating the budgeting indexes with the real material and man work costs for each activity and replicating it to all work packages from the line of balance.

It is important to replicate the results and improvements proposed on the company's future residential or commercial projects and to feed continuously the Standardized Work's reports with the new collected data in order to establish a database consistent with the company's practices and construction techniques.

6 Referencies

Carvalho, L. O., Heineck, L.F.M., and Edésio A. (2004). Uma crítica à utilização da técnica de observações instantâneas para obtenção de tempos produtivos, auxiliares e improdutivos em obra: Uma metodologia para obtenção das constantes orçamentárias de consumo dos serviços de construção. In: I Conferência Latino-Americana de Construção Sustentável - X Encontro Nacional de Tecnologia do Ambiente Construído. São Paulo: ANTAC.

Fernandes, N.B.L.S., Saggin, A.B., Valente, C.P., Brito, F.L. and Mourão, C.A.M.A. (2015) The Standardized Work Tool Applied to the Waterproofing Process With Acrylic Membrane. In: Seppänen, O., González, V.A. & Arroyo, P., 23rd Annual Conference of the International Group for Lean Construction. Perth, Australia, 29-31 Jul 2015. pp 133-142

Mariz, R.N., Picchi, F.A., Granja, A.D. and Melo, R.S.S.D. (2012) 'A Review of the Standardized Work Application in Construction' In:, Tommelein, I.D. & Pasquire, C.L., 20th Annual Conference of the International Group for Lean Construction. San Diego, USA, 18-20 Jul 2012.

Mariz, R.N. and Picchi, F.A. (2013) 'Application of Standardized Work in Franki Piles Concrete Work ' In:, Formoso, C.T. & Tzortzopoulos, P., 21th Annual Conference of the International Group for Lean Construction. Fortaleza, Brazil, 31-2 Aug 2013. pp 461-470

Mariz, R.N., and Picchi, F.A. (2013). Método para aplicação do trabalho padronizado. Ambiente Construído 13.3: 7-27.

Ohno, T. (1997). The Toyota production system: beyond largescale manufacturing. Portland: Bookman.