A REVIEW OF THE STANDARDIZED WORK APPLICATION IN CONSTRUCTION

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ABSTRACT

The utilization of standardized work in manufacturing has achieved many benefits, thus motivating researchers to apply them in the construction environment. The aim of this research is to identify gaps that involve standardized work applications inserted in the construction environment.

We adopted a literature review approach focusing on studies in construction sector that addressed standardized work applications. Subsequently, comparative tables of these publications were prepared and analyzed. Finally, opportunities to apply the standardized work elements, documents and tools in future works were identified. The article points out that there is a shortage in publications that address the application of these elements and tools in construction. From the construction flow analysis, we observed that almost all papers were applying job site flow. Standardized work elements analysis pointed out that the three elements (takt time, sequence and work in process) should be applied in the same process. The analysis of standardized work tools and documents showed that some documents have not been utilized in construction, they are: production capacity sheet, Standardized Work Chart and verification process sheet.

We also realized a lack of a method to implement the standardized work in construction. This paper contributes to standardized work expansion in construction environment by utilizing its elements, documents and tools.

KEYWORDS

Standardized work, Lean thinking, Construction.

INTRODUCTION

The construction industry is under pressure to improve production management practices, due to some factors, such as: low productivity, social demands, high levels of waste, and bad image when compared with other industries. An alternative that can change this scenario is Lean Thinking, as its implementation results in lead time and cost reduction and quality product improvement. Lean Thinking is the generalization of the Toyota Production System for other industrial sectors (Womack and Jones 1996).

Since the pioneering proposition by Womack and Jones (1996) regarding the five principles of lean thinking, the flow principle has been highlighted as a cornerstone of this philosophy. An element widely utilized to put in place this principle is standardized work (SW), which aims to keep the production as close to the continuous flow as possible (Liker 2004). SW reduces waste and work-in-process, reduces workload and risk of accidents, and increases productivity and employee satisfaction (Kishida et al. 2006).

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In the construction context, the application of SW is still embryonic, arousing the interest to be further studied. Some researchers have already made some applications of SW elements, documents and tools in the construction (Feng and Ballard 2008; Bulhões et al. 2005; Nakagawa and Shimizu 2004), but no research raised approached all standardized work elements, documents and tools. Thus, the aim of this study is to identify opportunities for the application of SW elements, documents and tools inserted in the construction environment, and to assess the potential benefits of these applications.

RESEARCH METHOD

The methodological approach used consisted of a literature review (from 2001 to 2010) addressing the production cell implementation in the construction environment. Figure 1 shows the steps followed in this research.

Firstly, we identified in the literature SW elements, documents and tools. After, 24 cases that implemented these elements, documents or/and tools were identified.

Secondly, we identified the main focus of these cases, and the construction flows applied (business, job site, design, supply chain, and use and maintenance) by Picchi (2001). In the third step we crossed the 24 cases with SW elements, documents, and tools, and we identified what of these elements, documents, and tools were approached in each one research. The next step was report benefits obtained using SW elements, documents, and tools.

Finally, we found the main gaps in the consideration of previous mentioned aspects taking into account time, space, and information linkages. Results were analyzed in detail and opportunities for broader applications of production cells in construction have been offered.

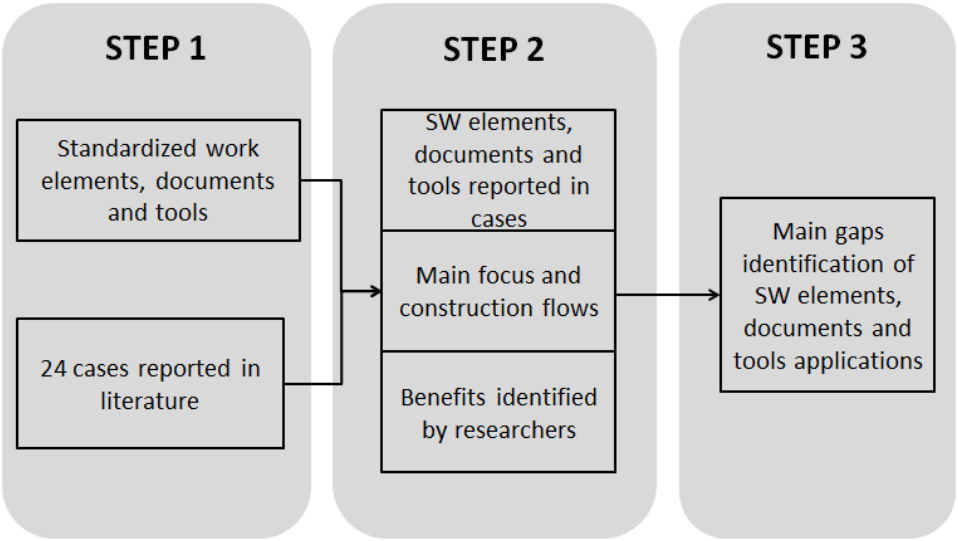

Figure 1: Steps followed in this research

STANDARDIZED WORK

BACKGROUND

The Training Within Industry Service (TWI) was established in 1940 during World War II to increase production output to support the Allied Forces war effort (Huntzinger 2005).

According to the same author, the "J programs" of the TWI developed and have a major impact on the manufacturing industry in the United States during the war. The "J programs" were: job instruction, job methods, job relations and program development.

The training method utilized today by Toyota is a replica of the developed material by the United States in the 1940s. Toyota made some minor additions and now utilizes the material to train thousands of workers (Liker and Meier 2007). The standardized work is a product of the program of job instruction, originating in the TWI (Feng and Ballard 2008).

ELEMENTS

SW means establishing precise procedures for each operator's work, based on three elements (LEAN ENTERPRISE INSTITUTE 2003):

- **takt time**: takt time is how frequently a product must be completed to meet customer expectations. It is calculated using customer demand and available time. Takt time sets the rhythm for standard work. (Rother and Harris 2002);
- **sequence**: sequence is the specific order an operator performs the manual steps of the process. The work sequence may be different from the process sequence. Focusing on the sequence identifies waste and stabilizes the process (Mondem 1998);
- **work-in-process (WIP)**: work in process is the minimum amount of inventory on the line that will allow the operator to flow product efficiently (Ohno 1997).

KEY DOCUMENTS

Documents are very important for implementing SW, but by utilizing only one document the results will be limited, as no document deals with all the elements of SW, thus it is necessary their combined utilization to achieve meaningful results (Marksberry *et al.* 2011). According to LEAN ENTERPRISE INSTITUTE (2003), three basic documents are commonly utilized in the creation of SW, they are:

a) Production Capacity Sheet: this is used to calculate the capacity of each machine in a set of process to confirm true capacity and to identify and eliminate bottlenecks (Mondem 1998);

b) Standardized Work Combination Table: this table depicts the combination of manual work time, walk time, and machine processing time for each operator in a sequence (LEAN ENTERPRISE INSTITUTE 2003);

c) Standardized Work Chart: this shows operator movement and material location in relation to the machine and overall process layout (Liker and Meier 2007).

ADDITIONAL DOCUMENTS AND TOOLS

Liker and Meier (2007) report that even in Toyota, in addition to the key documents of SW, additional documents and tools are needed to the SW application and management, they are:

a) Visual controls: they are utilized to facilitate the transfer of important information as quickly as possible. They are, indeed, ways to transfer just-in-time visual information in the factory (Suzaki 1987).

b) Policies and procedures: a support structure is provided by the company to support SW through its policies and procedures (Liker and Meier 2007).

c) Sample Models: they are tangible examples of the desired quality levels provided by the quality industry (Liker and Meier 2007).

d) Verification process spreadsheet: it is utilized in auditing SW. It has simple questions to help the employee develop a better work (Liker and Meier 2007).

e) Job instruction: workers are trained and instructed by their supervisors through defined methods to develop the knowledge and the skill of the worker (Mondem 1998).

f) Operator Balance Chart (OBC): it is a chart that describes the distribution of work between the operators in relation to takt time, based on actual data that is observed and recorded (Rother and Harris 2002).

The additional documents and tools referred are related to the need of basic stability, one important pre-requisite for flow and standardized work. is basic stability, emphasized by Rother and Harris (2002), and defined as stability on materials, men, methods and machines. Koskela (2000) refers to seven flows (information, material, previous work, following work, crew, equipment and space), that could be considered as conditions in the same direction.

RESULTS AND DISCUSSIONS

LITERATURE STUDIED ON THE APPLICATION OF THE SW ELEMENTS, DOCUMENTS AND TOOLS IN THE CONSTRUCTION

Table 1 shows the literature studied that contains applications of the SW elements, documents and tools in the construction context; in this table there are references to authors, objectives and application flows of these researches.

Table 1: Objectives and application flows in the literature studied on applications of the SW elements, documents and tools in the construction

References	Objectives	Application Flows
Feng and Ballard (2008)	To utilize TWI techniques to train and instruct employees within a concrete division of a company.	Design
Lima *et al.* (2010)	To map the value flow of the executive architecture design in a public agency and evaluate the results obtained.	Design
Bulhões *et al.* (2006)	To implement the continuous flow in the process of prefabricated assembly.	Job site
Bulhões *et al.* (2005)	To analyze possible implementation of continuous flow in civil construction.	Job site
Carneiro (2007)	To develop an implementation method of production cells, in the construction environment.	Job site
Carneiro *et al.* (2009)	To highlight the benefits of a successful production strategy.	Job site
Ferraz *et al.* (2005)	To describe a model of construction planning and management based on the Toyota Production System and the Theory of constraints.	Job site
Formoso (2002)	To facilitate the understanding of the principles of lean construction.	Job site
Francelino *et al.* (2006)	To present results obtained with the various improvements made in vertical works, based on the application of the lean philosophy.	Job site
Horman and Thomas (2005)	To identify if the optimum levels of inventory buffers interfere with the results of job performance.	Job site

Table 1: Objectives and application flows in the literature studied on applications of the SW elements, documents and tools in the construction (CONTINUATION)

References	Objectives	Application Flows
Kurek (2005)	To introduce the key elements of the principles of Lean Construction, in a construction company.	Job site
Miranda *et al.* (2003)	To structure the representation model of the Lean Construction through the establishment of the components that form the STP structure.	Job site
Nakagawa (2005)	To apply the visual tools and the documents of standard operating procedures to implement the Lean Construction.	Job site
Nakagawa and Shimizu (2004)	To reduce waste in the construction of buildings through the application of documents of standard operating procedures.	Job site
Patussi and Heineck (2009)	To describe the main results of the application of the concepts of cell production and the principles of lean production in a small construction.	Job site
Polesi *et al.* (2009)	To discuss the need for companies to balance the lack of standardization of activities and processes, also considering the desire for freedom of construction managers to find value and motivation in their work.	Job site
Santos *et al.* (2002)	Manufacturing cells concept application in a dry-wall service	Job site
Souza *et al.* (2005)	To report on developments from the completion of the first INOVACON module, which addresses the Lean Construction Philosophy	Job site
Tezel *et al.* (2010)	To understand how transparency in the processes is applied in the construction phase .	Job site
Nakagawa and Shimizu (2004)	To reduce waste in the construction of buildings through the application of documents of standard operating procedures.	Job site
Yu *et al.* (2009)	From the Value Stream Mapping, to create a steady flow of production to implement the lean Thiking in the building of houses.	Job site
Yu *et al. (*2007)	To reduce and manage the high variability in the construction process.	Job site
Benetti *et al.* (2007)	To identify deficiencies in the production process of precast artifacts that hinder the fulfillment of daily demand.	Supply Chain
Gallardo *et al.* (2006)	To stabilize and standardize the production of precast tile.	Supply Chain
Salermo (2005)	Lean thinking concepts and tools applied to hospital buildings maintenance	Use and maintenance

Overall, the papers discuss the applications or descriptions of Lean Thinking concepts and tools in the construction context, but in all of them it is presented SW applications of elements, documents and tools.

The research strategy most utilized was case study, with only two exceptions that employed action research (Gallardo et al. 2006; Bulhões et al. 2006). For the flows of application, we adopted the division proposed by Picchi (2001) that divides the construction into five major flows: business, job site, design, supply chain, and use and maintenance. Thus, it can be seen by examining Table 1 that most of the researches are in the construction flow. The other flows have applications of the SW elements, documents and tools, except the business flow.

STANDARDIZED WORK ELEMENTS, DOCUMENTS AND TOOLS APPLIED IN THE CONSTRUCTION CONTEXT

In this item we identified which SW elements, documents and tools were utilized in the studied literature, as shown in Table 2.

By examining Table 2, one can see that the most utilized tool reported in the literature was visual control, as several of the researches raised utilized the kanban, andon, 5-S program, visual pictures and other tools that facilitated the information flow through visual mechanisms. In second place, we identified the work-in-process element, as most of the works that utilized this element used supermarkets in order to ensure that

production would not stop. The takt time and sequence appear tied for third place in number of utilizations in the studied literature.

On the other hand, the following documents and tools were rarely utilized: OBC, sample models, job instruction, and standard procedures and policies, which may explain the failure of some of these applications, especially those waiting for the implementation of the continuous flow of production, because, according to Liker and Meier (2007), standard policies and procedures and job instruction are the basis for the SW establishment.

By analyzing Table 2, one can still see the non-utilization of three documents that could be adapted to the construction context, they are: production capacity sheet, verification of the processes spreadsheet and Standardized Work Chart. Although the production capacity sheet is related to equipment, in the construction it could be utilized, for example: concrete mixer, winch and other equipment. The verification of the processes spreadsheet can be utilized in an adaptation of the audit of the standardized work in the construction context; the Standardized Work Chart could be utilized as a layout, in which it would show the stock and work sequence on the floor, aiming to assist the implementation of various services, such as: masonry, plastering, laying of ceramic tiles, etc.

Table 2: Standardized work elements, documents and tools applied in construction

References	**SW Elements**			**SW documents**			**Additional SW documents and tools**						**Amount per article**
	Takt time	Sequence	Work-in-process	Production capacity sheet	Standardized work combination table	Standardized Work Chart	Operator Balance Chart	Visual controls	Policies and procedures	Sample models	Verification process spreadsheet	Job instruction	
Feng and Ballard (2008)												x	1
Lima *et al.* (2010)		x											1
Bulhões *et al.* (2006)		x	x										2
Bulhões *et al.* (2005)	x	x	x		x		x	x					6
Carneiro (2007)	x		x					x					3
Carneiro *et al.* (2009)	x		x					x					3
Ferraz *et al.* (2005)	x		x					x					3
Formoso (2002)								x		x			2
Francelino *et al.* (2006)*	x	x	x		x		x	x					6
Horman and Thomas			x										1
Kurek (2005)								x	x	x			3
Miranda *et al.* (2003)	x								x				2
Nakagawa (2005)								x					1
Nakagawa and Shimizu (2004)		x						x				x	3
Patussi and Heineck (2009)												x	1
Polesi *et al.* (2009)									x				1
Santos *et al.* (2002)								x	x				2
Souza *et al.* (2005)*			x		x			x					3
Tezel *et al.* (2010)								x		x			2
Yu *et al.* (2009)	x		x										2
Yu *et al. (*2007)			x										1
Benetti *et al.* (2007)	x	x			x		x						4
Gallardo *et al.* (2006)		x	x		x		x	x					5
Salermo (2005)		x						x					2
Qty of elements or tools	8	8	11	0	5	0	4	14	4	3	0	3	

Note*: These works refer to the Operator Balance Chart and Standardized Work Combination Table as man-machine diagram and sequence diagram, respectively.

The articles that have greater amount of application of these elements, documents and tools are: Bulhões *et al.* (2005) and Francelino *et al.* (2006) who also appear with the same elements, documents and tools. These two articles were the only that mention all SW elements, but they were not applied in the same service, for example: in the article by Francelino *et al.,* (2006), takt time and sequence were utilized in a service of dosage and transport of mortar; the work-in-process was utilized in ceramic bricks through the utilization of supermarkets. Thus, in none of the reviewed works a full application of SW has been noticed, for all elements should be applied to the same service for its full application.

BENEFITS OF THE APPLICATIONS OF SW ELEMENTS, DOCUMENTS AND TOOLS IDENTIFIED IN THE RESEARCHES RAISED

After identifying SW elements, documents and tools in the studied literature, Table 3 was devised. Table 3 depicts the benefits, identified by authors from the applications of the SW elements, documents and tools. It is noteworthy that the publications raised for this research showed other benefits, but we tried to highlight only the benefits from SW elements, documents and tools. Furthermore, some elements, documents and tools showed more than one benefit, for example: the article by Feng and Ballard (2008) utilized only one document (job instruction), but, according to these authors, through the utilization of this document, two benefits were achieved: increased productivity and employee training.

Table 3: Benefits of the applications of SW elements, documents and tools

Standardized Work elements, documents and tools	**Benefits**															
	Increased productivity	Cost reduction	Reduction in variability	Waste reduction	Reduction of manpower	Reduction of deadlines	Improvement in the information flow	Assistance in continuous production flow	Partnership with suppliers	Employee training	Reduction of stock	Pull production	Assistance in identifying and solving problems	Leveling of workload	Others	**Number of citations**
Takt time								3	1			3			1	8
Sequence	1		2	1		1	1	1								7
Work-in-process	1		5					6	1		3	2		1		18
Production capacity sheet																-
Standardized work combination table	1		1			1	1	1					2	1		8
Standardized Work Chart																-
Visual controls			1	1			10			1			5		1	19
Policies and procedures	1		2	1											1	5
Sample models			1				1						1			3
Verification process spreadsheet																-
Job instruction	1			1						2			1			5
Operator Balance Chart	2					1							1	1		5
Number of benefits	7	-	12	4	-	3	13	11	2	3	3	5	10	3	3	

For a more detailed analysis of Table 3, we decided to divide it:

a) Takt time: the two benefits that stood out in the utilization of this element were: assistance in the continuous flow of production and pull production;

b) Sequence: this element obtained five benefits, and reduction in variability was obtained twice;

c) Work-in-process: the two benefits that stood out in the utilization of this element were: assistance in the continuous flow of production and reduction in variability;

d) Standardized Work Combination Table: this document reached seven different benefits, and the assistance in identifying and solving problems was obtained twice;

e) Operator Balance Chart: it reached four different benefits, and the increased productivity was obtained twice;

f) Visual controls: the two benefits that stood out in the utilization of this tool were: improvement in the information flow and assistance in identifying and solving problems;

g) Policies and procedures: it showed four benefits, and reduction in variability was obtained twice;

h) Sample models: it showed three different benefits;

i) Job instruction: it showed four benefits, and employee training was obtained twice;

The benefits that are correlated with more SW elements, documents and tools are: increased productivity and reduction in variability; both appear in six of the SW elements, documents and tools.

CONCLUSIONS

This work shows that there are opportunities to expand the applications of SW elements, documents and tools for other flows, such as: design, supply, use and maintenance and, especially, business. Furthermore, researches in the construction flow are necessary to replicate the results obtained and also to achieve new results.

In relation to the applications of SW elements, we noticed a lack of more integrated applications, i.e., there are applications of the elements dispersed in various services, but we did not find the application of all elements in a single service. For a more integrated application, it could be tested the application of documents such as: OBC and Standardized Work Combination Table combined with a layout of materials and equipment, and a diagram of standardized work.

With respect to documents and tools, it is clear that some documents have not yet been adapted to the construction context, such as: production capacity sheet, Standardized Work Chart and verification of the services spreadsheet. Thus, this work has shown that they can be further exploited in the construction context.

The benefits that appear in more SW elements, documents and tools were: increased productivity and reduction in variability. We also noticed a lack of utilization of a method for application of the standardized work through the integrated utilization of its tools.

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ACKNOWLEDGEMENTS

To CNPq for the masters scholarship to the first author and to GTE (Group of Research and Extension on Management and Technology of Buildings).