Do Lean Methodologies include ergonomic tools?

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Abstract

This paper presents some methodologies for Lean implementation, highlighting which ergonomic tools are included in these methodologies. In order to achieve this, a review on ergonomic tools used to diagnostic work conditions was necessary. Being Lean Production, a well known work organizational model, widely implemented in all sort of industries and services companies in nowadays, it is important to include ergonomic tools for diagnose, evaluate and measure the workers conditions before and after the Lean implementation. Based on literature findings concern the existing Lean methodologies, it was possible to realize that none of the searched had these ergonomic tools implicit. In spite of this conclusion it was possible to identify the synergy between Ergonomic and Lean Production, encouraging the pursuit of a development a project that includes Ergonomic tools in a Lean methodology in order to assess the factors that impacts the worker ergonomic performance, before and after Lean implementation.

Keywords: Lean Production; Lean methodologies, Ergonomic Tools

1. INTRODUCTION

This paper presents some methodologies to implement Lean Production (LP), highlighting if these methodologies contain ergonomic tools to diagnostic, evaluate and measure worker conditions and human effort before and after Lean implementation. Evaluating these conditions is important to understand the current situation before the implementation of Lean and recognize if the current situation, is already deplorable or if it results from LP implementation, since, in the literature it is possible to find many detractors of Lean Production that see Lean as threat to workforce, imposing stressful work conditions. But, many times, this is result of misunderstandings of which Lean is and erroneous interpretations and ineffective implementations (Arezes et al., 2010).

Lean Production is a model of organization focused on the customer, seeking the elimination of waste (activities that add no value to the products) and on time quality products, materials and information deliveries. LP denomination, appeared in the book "The Machine That Changed the World", written by James P. Womack, Daniel T. Jones and Daniel Roos (Womack et al., 1990) to describe the Toyota Production System (TPS) (Monden, 1983). The TPS had its roots on the Toyota Company in the 50's, and his mentor was Ohno (1988). The LP has evolved into a philosophy of thinking, Lean Thinking (Womack & Jones, 1996), whose basic principles are: 1. Value, 2. Value Stream, 3. Continuous flow, 4. Pull System and 5. Pursuit perfection, as represented in Figure 1.

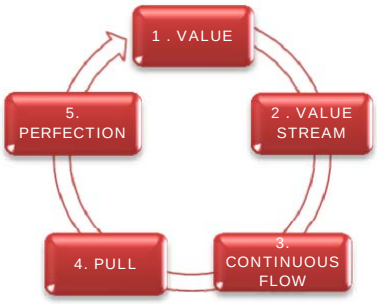

Figure 1 – Lean Thinking principles.

These principles imply the dedication of all people, being the last one - pursuit perfection (principle 5) - the principle that implies the strongest and continuously commitment of people in order to improve all the processes and activities in companies. This improvement has to do not only with the process and operations improvement as referred, but also, and more important, with the worker conditions and behaviours improvement. This is implicit on the key idea of LP: "doing

more with less" and less means less space occupied, less transports, less inventories, and most important, less human effort.

Traditionally, the worker conditions have been the main concern of Ergonomics. Ergonomics is a scientific discipline concerned with the understanding of interactions among humans and other elements of a system. It is a profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance (IEA, 2011). Based on the definition stated by Karwowski (1996), Ergonomics integrates knowledge from the humanities to adapt systems, products and environments to the skills and physical and mental limitations of individuals, studying the interaction between man and technology, in a continuous work conditions improvement. So, to achieve a good performance, the companies need to follow the technological developments but also to allow and give a good environmental work conditions.

To achieve the proposed objective of this work, it was necessary investigate Lean Production implementation methodologies and to understand if and how these methodologies consider tools to diagnostic worker conditions and measure the human effort.

The research methodology used was a literature review focused on the Ergonomic tools and Lean methodologies. The keywords used in the search were: "Ergonomic tools", "Ergonomics and Lean", "Lean Production", "Analysis Tools", and "Design".

This paper is structured in 5 sections. After the introduction of the work in section 1, it was reviewed some ergonomic tools highlighting their authors and the factor assessed by these tools. The third section presents the Lean methodologies reviewed in Maia et al. (2011), summarized and classified by the tools that are used in the methodologies. The fourth section discusses the main findings in the literature about the synergy between Lean and Ergonomics and the potential in exploring this. Finally, the fifth section presents some concluding remarks and future work.

2. ERGONOMIC TOOLS: A BRIEF INTRODUCTION AND REVIEW

Based on Wynn's[1] words "I learned about ergonomics as a way to optimize a work system, because a person is part of a work system. You have to understand that person's capabilities and design the work around their abilities. (...) Human-centred design is good industrial engineering, (...) and ergonomics has a huge impact on production efficiency at the workstation level". Hence, ergonomics ideally meets the needs of better productivity and worker health and safety all at once (Heston, 2006). So, and due to some misinterpretation, it is necessary to state that ergonomics is not a safety issue but is allied with this.

Ergonomic tools allow diagnose and evaluate worker conditions, providing the information to take decisions in order to improve them. The improvements will reduce the risk of diseases and work-related accidents. Good work conditions are essential for the workers develop their activity without being injured by this work. This will promote, at least, healthy environments that contribute positively for the productivity increase.

A wide number of factors influence the ergonomics performance. They are posture (sitting, standing, change of posture, hand and arm postures) and movement (lifting, carrying, pulling and pushing), information and operation (visual information, hearing, other senses, controls for operation, dialogues, website design, mobile interaction, virtual reality), environment factors (noise, vibration, illumination, climate and chemical substances) and work organization jobs and tasks (Dul, 2008). These factors also influence the health, safety, comfort and worker efficiency.

To evaluate the ergonomic conditions relating with these factors there are some tools, classified by some authors, for instance, Ligeiro (2010), as checklists, qualitative, quantitative and semi-quantitative criteria. Some of these tools are presented in the table 1, organized by author and by chronological order. Also, this table emphasizes the factor assessed, showing that for the same factor, different tools can be used, i.e., the posture could be assessed by the CORLETT, OWAS or REBA tool. The first one assess the posture discomfort using a map of the regions, the second assess the posture through observation of the collaborators and the last one evaluates the risk of developing musculoskeletal lesions based on an analysis of working posture. One of the reasons for using different tools to assess or evaluate the same factor is the tool reliability.

The last tool identified in the table 1 (Ergonomics checkpoints), a manual from the International Labour Organization (ILO), presents various checklists for assessing the materials storage and handling, hand tools, machine safety, workstation design, lighting, premises, hazardous substances and agents, welfare facilities and work organization. This manual, also, illustrate some useful examples of the improvements that can be achieved, at low cost.

[1] Mike Wynn, vice president and ergonomics engineer for Humantech (www.humantech.com), Ann Arbor, Mich.

Table 1. Ergonomic tools and factor assessed by them

Tool (Reference)	Factor assessed
CORLETT (Corlett & Bishop, 1976)	Posture Assess postural discomfort, using a map of the regions from the body
OWAS – Ovako Working Posture Analyzing System (Karhu et al., 1977)	Posture Assesses the postures assumed by workers through observation
Diagrama de Corlett (Corlett & Manenica, 1980)	Diagram of painful areas
NIOSH (Waters et al., 1993)	Load lifting Characterizes the load lifting
Checklist Michigan (Lifshitz & Armstrong, 1986)	Upper extremities Assesses the upper extremities of the workers in the workplace and list
RULA – Rapid Upper Limb Assessment (McAtamney & Corlett, 1993)	Upper arms/members Identify postures and efforts that contribute to the appearance of muscle pains and lesions in the arms
RODGERS (Rodgers, 1992)	Body segments Scans the level of effort, the duration, the time and frequency of these efforts establishing priorities
Strain Index – Distal Upper Extremity (DUE) (Moore & Garg, 1995)	Upper arms/members Establishes a rate for the biomechanics of the upper distal extremities
HAL – Hand Activity Level (Latko et al., 1997)	Manual activities Assesses the exposure in manual activities
OSHA – Occupational Safety and Health Administration risk filter (Silverstein, 1997)	Management of work Identify work environments that need to be evaluated
BORG Scale (Borg, 1998)	Effort
Ratings of Perceived Exertion scale (RPE)	Describes the perception of the workers for effort during the task
REBA – Rapid Entire Body Assessment (Hignett & McAtamney, 2000)	Posture Evaluates the risk of developing musculoskeletal lesions based on an analysis of working posture
HSE - Health and Safety Executive (Graves et al., 2002)	Upper arms/members Assesses gradually the risk of musculoskeletal disorders in the upper and identify risk factors
OCRA – Occupational Repetitive Actions (Occhipinti & Colombini, 2005)	Effort Characterizes task by frequency and effort required
Software TOR-TOM (Couto, 2006)	Ergonomic risk assessment, the establishment of tolerance limits and management solutions
Gilkinson (2007)	Organization of work space and the environment
International Labour Office (ILO, 2010)	All factors

3. LEAN PRODUCTION METHODOLOGIES

There are some methodologies to implement Lean Production reviewed by the authors (Maia et al., 2011) and presented in the table 2.

Table 2 – Some Lean Production methodologies and their authors.

METHODOLOGIES / REFERENCES	Monden (1983)	Ohno (1988)	Ahrens (2006)	Hodge et al. (2011)	Witcher & Butterworth (2001)	Liker (2004)	Yang & Su (2007)	Womack & Jones (1996)	Jackson (2006)	Wilson (2006)	Warwick Business School (2008)	SECORA Consulting (2007)	BRIEF Consult. (2007)	Salvada (s.d.)	Caldwell (2005)
1. TPS methodology (TPS met.)	X	X													
2. Hoshin-Kanri (HC)	X				X		X		X						
3. Lean Alliance methodology (LA)			X												
4. Toyota way (TW)						X									
5. Lean Impl. model for textile (LIMT)				X											
6. Lean thinking (LT)								X							
7. Kaizen methodology										X					
8. SLIM (Secora Lean Implementation met.)												X			
9. SLIM (Strategic Lean Implementation met.)											X				
10. Brief methodology													X		
11. Methodology A3 PDCA														X	
12. Lean Six Sigma															X

In these methodologies different tools were identified, and summarized in table 3. The first seventeen are considered Lean tools that will solve a great number of problems when a company embrace a journey Lean; the others are tools from Management and Quality areas used to prepare goals and strategic plans and diagnose the current situation, the strategy and the production system of the company.

Table 3 – Lean Production tools *versus* Lean Production methodologies.

LP methodologies	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
LP tools:												
1. 5S's					X			X				
2. JIT	X				X							
3. Jidoka	X											
4. Heijunka	X							X				
5. Standardized work	X				X							
6. Visual management					X			X				
7. Continuous improvement/ Kaizen	X				X			X				
8. Pull system	X									X		
9. Continuous flow										X		
10. SMED	X							X				
11. PDCA		X										X
12. DMAIC												X
13. VSM		X			X							
14. SMED		X			X							
15. TPM												
16. A3					X						X	
17. Policy Development	X											
Other tools:												
18. SWOT Analysis		X										
19. Porter Analysis												
20. Porter Matrix		X										
21. PEST Analysis		X										
22. Matrix product / market		X										
23. Matrix market/technology		X										
24. Diagnosis of the president		X										
25. Analysis Report A3 (A3-RA)		X										
26. Matrix X A3 (A3-X)		X										
27. Report problem-solving		X										
28. 5W1H											X	
29. 5 Why											X	
30. Fishbone											X	
31. Pareto chart											X	
32. Histogram											X	
33. Scatter Diagram											X	
34. Check sheets											X	
35. Control charts											X	
36. Flowcharts											X	
37. Radar Charts											X	
38. Tree diagram											X	
39. Brainstorming											X	

Based on the collected information on the available LP methodologies and the correspondents' tools, and summarized on table 2 and 3, it was possible to verify that all the tools used are not ergonomic tools. However, some tools like 5S, Standardized work, SMED, Kaizen includes safety and ergonomics aspects and benefits for the worker, for example, less accidents due to adequate equipment and instructions about how to use; less confusion in the workstation; less effort, exhaustion, stress and frustration; more responsibility and moral (Bittencourt et al., 2011).

4. FINDINGS AND DISCUSSION

Nowadays, it is common to designate the 5S tool, 6S, being the 6th sense the sense of Safety (Leff, 2011). This author explains how company safety officials can use Lean initiatives to reinforce their safety programs, through the elimination of the 7 wastes: 1) overproduction (overburdening of employees); 2) unnecessary transportation (and actions of employees); 3) inventory; 4) motion; 5) defects; 6) over-processing and 7) waiting. All these forms of wastes makes the system more complex and confuse with more WIP, more idle time, more materials transports, more motion of the operators, more shadow and dark areas, after all, more opportunities to happen accidents and injuries. Applying the 5S tool, all space will be cleaner, organized, classified and normalized (without unpredictable negative "surprises" such as a cut on a hand because of a sharp tool in the wrong spot) having as a result more safety. As Wilson-Donnelly and co-authors highlighted, the organizational approach has impact on the development of a company safety culture and

influence the adoption of good practices to avoid related work-accidents (Wilson-Donnelly et al., 2005). Others tools, like Kaizen and Poka-Yoke mechanisms improve process safety leadership and field work team performance by focus in the reduction of residual risk (waste) or activities that provide no/limited risk reduction, employing team-based methods as Process Hazards Analysis (PHAs), emergency preparedness reviews, Job Hazard Analysis (JHA) and successive checking (van Scyoc, 2008).

The synergy between Lean and Ergonomics have been recognized by others authors, namely Gilkinson (2007) that show that when combined, they successfully conduce a company to reduce risk and improve the system. Heston (2006) considers ergonomics as the first step to Lean implementation, being the resistance to the change reduced when workers were involved in their work space improvement. The Lean Thinking principles aligning with the Ergonomics becomes possible the Ergonomics principle of "working smarter, not harder" (Walder & Karlin, 2007).

Material handling and the layout are two of a set of practices considered to be essential for the Lean implementation. The material handling defines the way that material is handling during the process and the layout is the arrangement of the facilities in a factory. Both could increase the manufacturing lead time and the related costs. For a good Lean Production implementation, it is necessary flexible layouts, reducing movements of both materials and people, minimize material handling losses and avoid inventories between stations (Wong et al., 2009). Ergonomics should be considered since it will help the workers to improve productivity, reduce injuries and fatigues, by reducing unnecessary gesture and handlings that directly enhance the quality of products. Above, in the section 2, the ILO manual referred some checklists relating the material handling and ergonomics. As an example, Figure 2 and Figure 3 illustrate some photos of handling material, taken by the paper´s authors in a Portuguese company. Figure 2 shows two illustrations of load lifting (roll of tissue) assuming an incorrect posture a) and assuming a correct posture b).

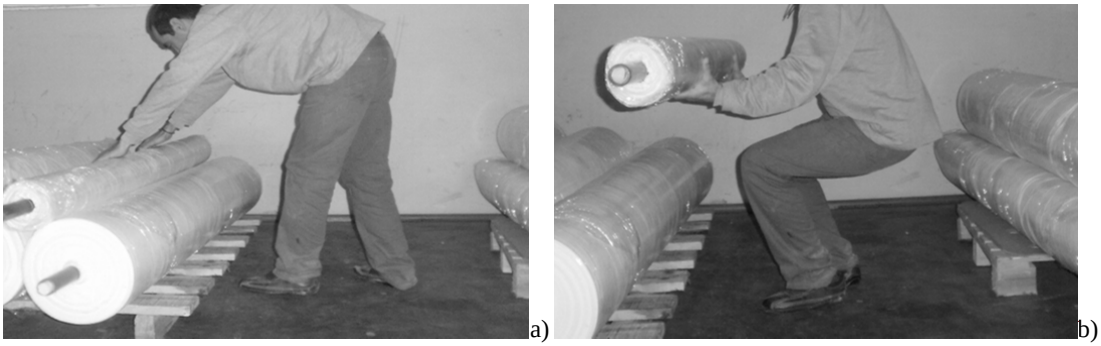
a) b)

Figure 2 – Load lifting assuming a correct posture a); and an incorrect posture b)

Figure 3 shows an example of an improper trolley to the load transported, causing discomfort for workers and provoking load damage or accidents, and putting in risk the workers safety. It is possible to see in this example that the load dimension (in this case, the length of the roll of tissue) is longer than the trolley.

Figure 3 – The load transportation using an improper trolley

In order to design Lean assembly lines without wastes related with unreasonable mental or physical burden, Eswaramoorthi et al., (2010) applied the RULA method to measure a large set of operator posture parameters and assessment of ergonomic stresses. U-shaped manufacturing cells are also designed with particular care for the workers ergonomic (Payton, 2006). This concern of designing assembly lines to mitigate operator workload comes at long time in Toyota Production System (Monden, 1983) that in order to evaluate the workload or fatigue rate of each process developed the Toyota Verification of Assembly Line (TVAL). This method used equations to measure the workload or fatigue rate of each assembly line operation.

In spite of the evidences presented above about the synergy between Lean and Ergonomics, the methodologies presented in the table 2 do not include a tool that allows measuring the effort involved in the activities, before and after the application of these tools. The absence of some tools that measure this effort creates many doubts about the Lean intention in reducing the human effort and promoting a healthy work environment. In the literature it could be found many papers about the threats for workplaces ergonomics in Lean environments as demonstrated in the review work of Arezes et al. (2010).

5. FINAL REMARKS

There are various ergonomic tools to assess factors that influence worker performance. Factors like the posture or the environment factors must be assessed before any changes (e.g., a Lean implementation) take place in the shop-floor, at a cost of having disappointed and discouraged results, ensuing from unknown variables. Based on the methodologies reviewed, it was possible to witness that none of them, until now, included ergonomic tools, having the question on the title of this paper, a negative answer. However, it was possible to perceive alignments between Lean and Ergonomics and how these initiatives fit well each other. The authors will continue to review LP methodologies in order to highlight if and how these could addresses the worker conditions and human effort in companies employing Lean tools and cultivating a Lean work environment.

As a future work, the research team wants to develop a Lean methodology that will include some ergonomics tools to diagnose ergonomic current situation and measure the effort demanded before and after the Lean implementation. In this way, the workers' well-being and their satisfaction could be increased creating a good environment important to health and performance.

6. ACKNOWLEDGMENTS

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