Threats and Opportunities for Workplace Ergonomics in Lean Environments

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Abstract
Lean Management Systems (LMS) have become very popular among the manufacturing industry, services and large commercial areas. A LMS must develop and consider a set of work energizers to bring compatibility with workplace ergonomics, namely at a muscular, cognitive, and emotional demands level. The goal of this study is the identification of the most relevant impacts of a LMS adoption from the ergonomic point of view and cited in the literature and the synthesis of some possible drawbacks in workplace ergonomics due to a flawed application of the LMS. A final discussion about the most important, positive and negative, impacts are present at the end of the paper.

Keywords: Lean Management System, ergonomics, work organization models

Introduction
Lean Production was the term used by Krafcik in 1988 to nominate the system used in some Japanese automotive plants installed in U.S. during the 80's (Holweg, 2007). This system, called Toyota Production System because of its origins in Toyota automotive plants (Monden, 1998), becomes known since the first oil crisis in 1973. Despite the crisis, Toyota results were remarkable provoking the curiosity of other plants. Their capacity in designing and building cars in less time with fewer people and lower inventories were remarkable. This crisis also motivates the research of automotive industry studies through one program totally dedicated to this issue, the International Motor Vehicle Program (IMVP) at MIT. One of the first of many studies that result from this program was the survey published in the book *"The Machine that changed the world"* from Womack et al. (1990) about the differences between the Western and Japanese automotive practices. According to several publications, the Lean Thinking focus in the waste (*muda*) elimination, i.e., everything that does not directly contributes for adding value to a product, under the perspective of customers' needs and requirements and is based in five principles: i) create value for the customer; ii) map the value stream; iii) create flow; iv) the customer pulls the production and v) pursuing perfection. To achieve these principles it is indispensable the application of two key concepts: JIT production and continuous improvement (*kaizen*) (Imai, 1997). The

continuous improvement is linked to another lean thinking: the creative thinking, pointed out by TPS as another key concept (Monden, 1998). This concept has to do with the will of the workers and culture promoted by the companies to extend the principles to all management activities.

Being the workers so important in LMS it is important guarantee that they feel well and that their Health and Safety are assured. Nevertheless, it is possible to find out in the literature a significant number of papers addressing negative aspects of the LMS implementation regarding the workplace ergonomics. Fortunately, there are others that appointed positive aspects. Despite some dispute about the positive and negative aspects of the LMS implementation, it seems that there are arguments for both "sides".

In this scope, this study aims at identifying the most relevant impacts of LMS implementation regarding the ergonomic working conditions and discuss some possible drawbacks about the flawed application of LMS.

Methodology

This paper is based on a systematic literature about the proposed subjects comprising all the published sources that were considered to bring relevant information.

As a regular literature review, the present paper discusses published information in a particular subject area, and within a certain time period. So, this literature will focus in the LMS and its impact in the occupational ergonomic conditions, as well as in the workers' Health and Safety. Some concepts and work organization models are also reviewed and presented to contextualize the paper objectives. In this scope, it is important to distinguish between the work on the Fordist/Taylorism, Socio-Technical System (STS) and Lean systems. This contextualization is important because the threats and opportunities for workplace ergonomics that could emerge from Lean environments are different according the work organization model implemented in a company.

As some previous works have focused in similar reviews goal and included all the relevant literature during the 1980 and 1990's, it was decided that the present work would focus in the review of the more recent publications, i.e., documents published in the last decade, from 2000 onwards. The literature review included papers on all the defined subjects, namely about lean production/management systems and occupational ergonomics, or other working conditions issues.

The first step of the analysis consisted of searching for relevant articles/studies. The search was limited by the studies' date and to academic journals, thesis and other published documents available online. Therefore, all the unpublished works, including personal communications, were excluded from this analysis.

As a non-extensive list of the used keywords, it is possible to mention, for example, "Lean Manufacturing", "Lean Management Systems", "Lean Thinking", "Lean Management", "Ergonomics", "Health and Safety", "Workplace conditions".

According to the mentioned procedure, the presented literature review included empirical and theoretical quantitative or qualitative studies focused on the topic of LMS and its relationship with the working conditions that were written in English.

Brief review of Fordist, STS and Lean teams

Fordist and STS

Henry Ford adopted the Taylor´s *Principles of Scientific Management* (1911) to his automobile factory to improve productivity. These principles were simple and, mainly,

consist in dividing the operations in elementary tasks that anyone could do. Each operator stays permanently in one workstation doing his simple and monotonous task with a standard time previously estimated by the Time and Methods staff. Functions like products or process design, production planning and control, quality control or decisions to be made belonging to other personnel staff or management. This exclusion of these functions, keep the operator without responsibilities and exclude him from the active participation on the improvement of processes and products.

The emphasis is on the individual and on the individual specialization in executing one task at some point in the moving assembling line. This work organization model restricts the mobility of operators between tasks, their participation in solving problems and their creativity. For these reasons, this work organization model imposes severe and hard work conditions, considering this a gear of the "big machine" totally dependent on the equipments, reason to called this system a techno centric system.

Contrasting with this techno centric system is the Socio-Technical, or Anthropocentric, Production System, defined as a system based on the utilization of skilled human resources and flexible technology adapted to the needs of flexible and participative organization (Kovacs and Moniz, 1994). The STS breaks totally with the Fordist system, by promoting the operators' qualification, teamwork and giving power and autonomy to the team operators.

Lean Teams

Many authors see work organization in LMS as an evolution with some deviations from the Fordist system, being the job rotation and teamwork two of these deviations. Björkman (1996), for example, referred that teamwork is restricted to Quality Circles, and to the activities of cleaning and housekeeping. Also, van Amelsvoort and Benders (1996) discussing the Toyota "team", considers that this team did not have autonomy, only a set of duties and responsibilities. Others authors, like Forza (1996) considers that the workers were structurally stimulated to move to a different dimension of responsibility that combines its own with the companies' responsibility in a manner of obtaining the greatest employee willingness.

This lead to a different concept of teams - *Lean Teams* – that emerges as something different from the socio-technical teams discussed early. In this concept remains the same concern of improving the working conditions for operators and stimulating the satisfaction on the work. For instance, the training and the job rotation had been strategies adopted to familiarize the workers with a range of tasks. These permits to the workers more understanding in the scheduling problems and solving that, to balance the workload, prevents ergonomic problems from the repeated operations and to avoid the work monotony (MacDuffie and Pil, 1994).

Literature review results

Generically, and as pointed out by many authors, such as Saurin and Ferreira (2009), the identification of the possible advantages and disadvantages related to the implementation of a LMS is highly dependent of the discussed contexts and also on the type of production shift observed at the time of the LMS implementation.

Despite some dispute about the positive and negative outputs of the LMS implementation, it seems that there are arguments for both "sides". Overall, almost a half of the analyzed papers and topics referred to positive impacts, or opportunities, and the other half to negative impacts, even though, many of these studies indicated that both impacts occurred simultaneously.

Accordingly, it was decided to present some transversal issues regarding the impact of the LMS and, in the last part of this section, a compilation of the most cited positive points and drawbacks resulting from the LMS adoption.

Work pace, intensity and load

Some of the main cited drawbacks of LMS are the standardization of cycle time, which prevents workers from managing their own work pace (Eklund and Berglund, 2007), the need to be multiskilled (Genaidy and Karwowski, 2003), which often implies job enlargement and work intensification, by the unlimited demands on performance, the willingness to work overtime very frequently and at very short notice and a close individual surveillance and pressure (Saurin and Ferreira, 2009).

In terms of workload and regarding its content, it can be assumed that the need to reduce the work cycle will imply that the work will tend to be more repetitive and intense (Saurin and Ferreira, 2009). As also pointed out by Genaidy et al. (2003), the reduction of the work cycle to values less than 60 seconds, which according to authors are typical in LMS, will have a negative impact on workers' well-being. However, other authors, such Hunter (2002), mentioned that Lean production uses less human effort.

Angelis at al. (2004) emphasized that in some activities there is a need to maintain a certain high level of work pace during long periods. According to those authors, these activities are, most likely, very highly demanding and, in accordance, need to be designed for an execution at a maximum of 80% of the maximum work pace and including the participation of the workers in the planning of his/her activities. Also Shoaf et al. (2004) mentioned that he majority of the negative impacts come from the lack of workers' involvement in the project of their own activities.

Ferreira (2006), citing previous works, referred that in some cases the ideal work pace should not be imposed to workers but they may have the freedom to control their own work pace. For this "self-definition" of the work pace, also viewed as a sort of autonomy, it will be important to consider some basic aspects, for example, the need to preview the availability of intermediate points for product storage. Additionally, some studies, (Genaidy and Karwowsky, 2003; Ferreira, 2006; Eklund and Berglund, 2007) also refer that the LMS principle of reducing all the inactivity periods may also induce an increase in work intensity.

Worker motivation, satisfaction and stress

One of the most cited negative effects of the LMS is the stress levels registered among workers. Although the effects that can result from a LMS implementation may be seen as contradictory across the literature, it seems that there are some consensus in the potential for an increase level on the stress levels observed among workers (Anderson-Connoly et al., 2002, Angelis et al. 2004, Seppälä and Klemola, 2004).

As pointed out by Dul et al. (2009), Lean production and business process re-engineering focused on improvements of business processes in order to cut costs and serve customers better, which are likely to involve the need to downsize. Some of these strategies have been linked to reduce employee wellbeing. For example, the individual's perception of the downsizing process itself also appears to affect health (Kivimaki et al., 2001; Pepper et al., 2003). At this respect, Parker (2003), based on a longitudinal study, has shown that the implementation of a LMS result in job depression and reductions in job control and skill utilization. However, Conti et al. (2006), in a study of 21 different companies, found that the stress in lean implementations was related to implementation and operational decisions rather than inherent problems with the lean system.

Dul (2009) refers that, despite the fact that new forms of work (including LMS) are seen as improvements in working conditions, at the same time, a long series of negative tendencies are visible in working life, such as the increased number of people on long-term sick leave and with work related injuries, burned out personnel, stressed people, and overburdened people (Carayon and Smith, 2000).

Carayon and Smith (2000) also referred that various theories of job design can help in the definition of the positive and negative characteristics of the work system. For instance, theories of occupational stress have defined work stressors that are negative characteristics, such as high workload, shiftwork, low job control, high role ambiguity and role conflict. Theories of job design have also specified positive characteristics such as high task variety, feedback, opportunities for learning, and autonomy.

Some of the possible positive outputs of the LMS implementation are related to some work aspects that can improve workers motivation and satisfaction, these includes job stability, an hierarchical level decrease, as most of the employees enjoy a similar status, and the high qualification of the workforce (Saurin and Ferreira, 2009).

Considering also the workers' opinion, Eklund and Berglund (2007) have also reported that after the introduction of Lean Production in two manufacturing companies, the employees in production were more positive than negative to the new production system, identifying also both positive and negative aspects of the production concept.

Autonomy and participation

Two of the most important requirements for an effective implementation of the LMS are the workers' commitment with the company performance and the job enrichment (sometimes also called job enlargement), considering the workers' skills and activities. This enrichment assumes that workers will need to identify and control work variations, that they reorganize and improve production within their jobs.

There are some studies (Genaidy and Karwowski, 2003) referring that a LMS is characterized by a significant decentralisation of the authority and the attribution of a great degree of autonomy to each worker. This involvement of workers seem to be positively reflected in the working conditions improvement, as long as it is assumed that a large diversity of activities, skills and responsibilities tend to enrich the job content and thus minimizing work monotony and isolation (Seppälä and Klemola, 2004). However, other authors (Godard, 2001, Angelis et al., 2004) also consider that the same characteristics may results in a more stressful job. A few authors, for example Johansson and Abrahamsson (2009) and NIOSH (2002), consider that workers' power and autonomy to decide is relatively modest, as it is often 'overlooked' due to the need to increase the work intensity and pace (Saurin and Ferreira, 2009).

In terms of autonomy, some authors (Lewchuck and Stewart, 2001, Seppälä and Klemola, 2004) consider that the workers' autonomy in LMS is also modest, as most of the workers follow some imposed rigid work patterns, which tend to limit their freedom to decide about their work.

Some authors (Zink, 2000) also considered that the observed "Lean Management wave" has weakened the ergonomics structure within companies, by reducing costs with Health and Safety (H&S) and Ergonomics staff. At this respect, some studies reported that some changes were observed in terms of the companies' safety culture (Li, 2007). According to Saurin and Ferreira (2009), some studies mentioned that top management's commitment to H&S issues had increased due to LMS and this subject was no longer considered to be a specific concern of the H&S staff. However, Li (2007), in a literature review regarding lean practices and experiences, also noted that

employees' report quite different experiences of work effort, health and safety and relations with management.

Health outcome

As mentioned, the major cited workers' health outcome related to LMS is the increase in stress levels. However, there are other possible health outcomes that are related to LMS and mentioned in the literature. For example, Genaidy and Karwowski (2003), pointed out that, at least from a theoretical point of view, a true lean production model may imply a demand of the workers' muscular, cognitive, and emotional resources to the limit. Other authors, such as Colombini and Ochipinti (2006) referred that it is still unknown to what extent the organizational changes are helping to reduce musculoskeletal problems of assembly and other routine tasks of manufacturing or if, in turn, they are initiating new occupational risks in their turn.

It is also possible to find a frequent citation of the relationship between the LMS and the appearance of high rates of Work-related Musculoskeletal Disorders (WMSD). For example, Eklund and Berglund (2007) mentioned that in jobs with ergonomic stressors, intensification appears to lead to increases in WMSD. The same authors referred that LMS main criticism is that the lean working conditions were very demanding and that the risks of stress-related disorders including musculoskeletal disorders were high. Other critics claimed that Lean Production in principle did not differ from Taylorism.

Kazmierczak et al. (2004), gone further and referred that some ergonomics problems have been associated with lean environments, but also referred that it is possible that problems were possibly a consequence of production system rationalizations. In accordance, LMS and Total Quality Management (TQM) have been claimed to contribute to poor ergonomics and cause musculoskeletal disorders.

Assuming the adoption of some typical lean practices, Johansson and Abrahamsson (2009) reported that the return of the assembly line also creates problems at the working conditions level. Winkel and Westgaard (2005), also mentioned that, in general, a lean environment tend to represent an increase risk for one-sided work movements and physical over exertions, contributing to the potential development of WMSD.

Surprisingly or not, a set of papers argument exactly the opposite point of view, i.e., that the implementation of LMS tend to increase workers quality of life by introducing some improvement in their occupational environments.

According to some authors, the proper adoption of LMS may result in positive health effects, including the reduction of chronic and traumatic worker injuries (Hunter, 2008). This author, for example, referred that the usual goal of the LMS cell designer is to promote job enlargement, and not job simplification. Accordingly, job enlargement will result in better ergonomics, for example, by including additional time to do the additional work it will allow the human body to "heal microinjuries", which, according to the author, are related to chronic WMSD.

In LMS it is also usual to find workers with a variety of tasks, implying and requiring that workers been standing and walking. According to Hunter (2008), walking can be beneficial to workers wellbeing, as the walking benefits include the reduction of the risk for deep-vein thrombosis, increased bone strength, reduced cholesterol and blood vessel plaque, and healthier hearts. Additionally, Balasubramanian et al. (2008) referred that working in a dynamic standing posture reduces the fatigue and promote workers' mobility, being this important to work in lean cells.

Saurin and Ferreira (2009) also reported that, when comparing LMS and other production paradigms, some authors revealed that lean production cell was superior concerning ergonomics and some physiological factors, like postural analysis and

manual materials handling. But in their study, carried out in a harvester assembly line, they also referred that they do not identify a particular focus in the prevention of cumulative trauma injuries, despite the strong emphasis on accident prevention.

After the previous synthesis of the literature review, it is possible to briefly present the main results regarding the advantages, or positive points, related to LMS and also the main disadvantages. This list was obtained through the carried out literature review and by aggregating the diversity of factors cited in the literature (Table 1). The list was also based in the compilation proposed by Ferreira (2006).

Table 1 - Brief list of the main cited advantages and disadvantages of LMS implementation

Advantages	Disadvantages
hierarchical level decrease	decrease of workers' autonomy
high qualification of the workforce	increased risk of WMSD development
workers' participation and engagement	individual pressure/surveillance
job enlargement/enrichment	job enlargement
less human effort	LMS perceived as 'modern' Taylorism
teamwork increase	multi-skills requirements
workers' autonomy increase	stress increase
workforce perceived as central element	inflexible work pattern
	work pace increase
	work intensification

Discussion

A brief review about the work organization models explains how those models influence workplace conditions in different manners. However, probably due to the LMS popularity, the way these organization models influenced working conditions had been largely discussed in the literature, as demonstrated in the above section. It is important to notice that the aspects in Table 1 have to be contextualized in the work organization existed in the company, as it very different moving from a Fordist system or Socio-Technical System (STS) to a LMS.

The negative aspects mentioned can be transformed in positive depending on the previous work organization. One example of this is the workers' autonomy that appears in both sides of the table. In LMS this autonomy can decrease when compared against the STS because this autonomy is seen as an objective to be achieved by the balance between social and technical sub-system (Cutcher-Gershenfeld et al., 1994).

It is unquestionable that working in teams is an important requisite for the current work organization models. Although, production teams like the cell layout teams or problem-solving teams like the Quality Circles are in the heart of the company and, most of the time and for most people, they promote a better workplace through more work satisfaction. Based on the literature, it was constructed a Causes and Effect Diagram (Figure 1) showing the characteristics of Lean Teams working in cell layout as causes that conduces to better workplace. Some of these causes could be seen as provoking more stress to workers, mainly if they are workers that enjoy working alone or if they see more duties and responsibilities as a signal to work more without had been paid for this. The solution to this could be training the workers in teamwork and problem-solving issues like some companies do that are, already, implementing LMS.

The main objective of this paper is the identification of the most relevant impacts of LMS implementations from the ergonomic point of view based on the literature review but it is intended that authors' experience (and previous research) may be also included in the following discussion.

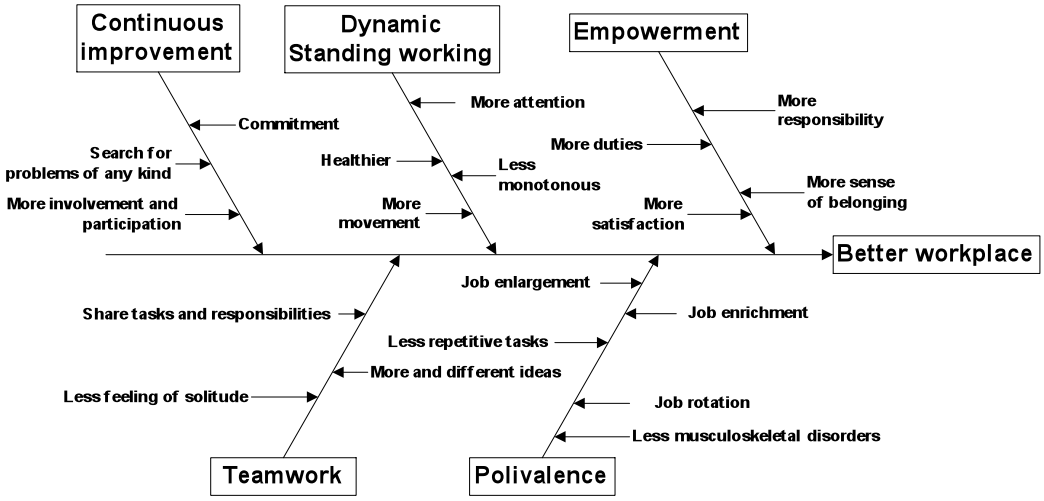

Figure 1 – Causes and effect of working in Lean cell layout.

If looking at the basis of LMS it is possible to see the continuous pursue of waste elimination, called *Muda*, as well as the elimination of *Mura* and *Muri*. Since this paper is also about human factors, it should be paid attention to the concept of *Muri* elimination. The Japanese word *Muri* means physical strain or overburdening. Any actions such as "bending to work", "pushing hard", "lifting heavy weights", "repeating tiring actions", and "wasteful walk" are considered *Muri* and consequently they must be eliminated if we are following the LMS principles. Any implementation of LMS that does not reduces *Muri,* or even worse is increasing it as some publications report, should not be considered as fully representing the *'spirit'* of the LMS implementation.

Going a bit deeper into the practical implementations, we may find that the implementation of some lean techniques may effectively lead to negative impacts in terms of human factors, as the ones referred in the literature.

One of the techniques that may lead to some discomfort among workers is the Standard Work technique. This technique can be described as the detailed definition of operations where a standard cycle time and standard Work-In-Progress are also defined and should be followed by the worker. The operations must be followed exactly as it is defined and there is no margin for improvisation (referred as inflexible work pattern). The aim of such restrictions is related to the elimination of *Mura* (variability), improving quality, safety, and planning effectiveness. In many Standard Work implementations it is possible to observe workers' disapproval, since they may feel some lose of flexibility and autonomy. In many cases, after some time, they may see the benefits of such implementations and the initial stress gradually disappears. It should be pointed out that the worker is free to propose different standards to be applied if he/she finds better ways of performing the same task.

Another drawback reported in many publications is the increased risk of WMSD development. This may be caused by the repetition of the same movements for long periods. Any solution that results in this type of disorders is considered as *Muri* and, accordingly, it is not acceptable under lean principles. When short cycle times are present some solution, such as "rabbit chase" or forcing the workplace rotation among workers, should be implemented. In some cases, the workers show some resistance in the beginning but normally the success is achieved after a small period.

The reported negative impacts of lean implementations in terms of work pace increase and the work intensification perceived by workers may be real issues. Lean

implementation implies also the better use of the workforce. Solutions are developed to use the workforce in adding value during most of their working time. During lean implementations, it is necessary to eliminate non-value adding activities, such as people waiting for material, orders, or searching for tools, for transport equipment, walking, transporting materials, monitoring equipment, etc. The final result will be a higher 'use' of people in value adding activities. Good lean solutions must be the ones that, although increasing the efficiency in the use of the workforce, also improve the working conditions resulting in an increase of team spirit and motivation among workers.

The LMS principles are focused on improving working environments by creating appropriate workplaces, team spirit, challenges, motivation, flexibility, cross skills, responsibility, autonomy, and so on. From the literature review and authors' experience, if those goals are not achieved it is likely that the developed LMS solutions are not really lean.

Concluding remarks

Although the large amount of published papers about LMS and its consequences for the working conditions, it seems that almost a half of the analyzed papers referred to positive impacts, or opportunities, and the other half to negative impacts, even though, many of these studies indicated that both impacts occurred simultaneously.

The principles of lean management should not lead, by definition, to any one of the reported drawbacks in terms of workplace ergonomics. The reported disadvantages, or possible threats, of LMS implementations may result from the misunderstanding of the lean principles and possibly by implementing similar solutions that may be effective in a specific work context but not suitable to all the possible situations.

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