PAPER REF: 4035

PREPARATION OF A TEXTILE AND CLOTHING COMPANY TO LEAN IMPLEMENTATION BY IDENTIFYING ERGONOMIC AND ENVIRONMENTAL RISKS

Laura Costa Maia[1 (*)], Anabela Carvalho Alves[1], Celina Pinto Leão[2]

[1]Centre for Industrial and Technology Management, Department of Production and Systems, School of Engineering, University of Minho, Guimarães, Portugal
[2]Centro Algoritmi, Department of Production and Systems, School of Engineering, University of Minho, Guimarães, Portugal
[(*)]*Email:* id2932@alunos.uminho.pt

ABSTRACT

This paper intends to identify ergonomic and environmental risks, in the different sectors of the Portuguese Textile and Clothing Industry (TCI). This identification will be used in order to have a better understanding of the risks in each sector of TCI. Knowing these risks, some more focused proposals oriented by a Lean methodology, could be recommended to eliminate them more rapidly. The Lean methodology to implement Lean in TCI is already in development and includes ergonomic and sustainable tools to solve the problems related with the identified risks. These tools will allow analysing and evaluating the risks to improve the work environment.

Keywords: Ergonomics, Lean Production, Sustainable tools, Textile and Clothing Industry.

1. INTRODUCTION

Lean Production (LP) (Womack et al., 1990) is a well-known work organizational model being, nowadays, widely implemented in all sort of industries and services companies. LP responds to customers' demand for on-time delivery of high quality products at reduced costs, through continuous waste elimination, respecting people and environment.

To implement LP in Portuguese Textile and Clothing Industry (TCI), the authors proposed a methodology (Maia et al., 2012a). Briefly, this methodology is divided in three phases: 1) preparation of work environment and people; 2) implementation of methodology and 3) evaluation, standardization and sustainability, considering different dimensions: the ergonomic dimension, the sustainability dimension, the operational dimension and the human capital dimension.

TCI can be segmented into different sectors: spinning, weaving, knitting, dyeing, finishing, printing, stamping and clothing. The identification of environmental and ergonomic risks will be specified for each sector. Ergonomic risks include lighting, fire risks, posture risks, movements, heavy loads to lift among others. Environmental risks include noise, dust and fibers thermal environment gases and steam radiation, vibrations, biological agents, and also include water, air and soil pollution and raw materials, energy and water consumption in excess, among others. Environment risks are a type of environmental wastes that are also discussed in this paper.

The objective of this paper is to identify those risks for each sector of TCI in order to know them and understand better the risks involved and environmental wastes in a context of LP implementation.

2. LEAN PRODUCTION DEFINITION AND CONCEPTS

Lean Production (LP) is a work organizational model focused on the customer and delivery on time quality products, materials and information without any wastes, i.e., activities that add no value to the products from the point of view of customer, respecting people and environment. This mean "*doing more with less*" where less implies less space occupied, less transports, less inventories, and most important, less human effort and less natural resources. The origin of LP is the *Toyota Production System* (Monden, 1983; Ohno, 1988), which became known as *Lean Production* in the book "*The Machine that Changed the World*" (Womack et al., 1990). TPS employ two pillars: JIT (Just-In-Time) production and autonomation (*Jidoka* in Japanese) and many tools such as Standard work, *kaizen*, *heijunka*, among others, to reduce product lead times and cost. Also, identify two key concepts that is flexible work force (*Shojinka* in Japanese) and creative thinking or inventive ideas (*Soikufu* in Japanese) that means capitalizing on worker suggestions (Monden, 1983).

Ohno, in Ohno (1988), has identified seven wastes: overproduction, transports, movements, waits, over-processing, defects and inventories. Others wastes were identified by others authors (Liker, 2004; Bicheno, 2008): untapped human potential; make the wrong product efficiently; inappropriate systems; wasted energy, water and natural resources. The implementation of Lean tools is a powerful way to eliminate these wastes.

Lean Thinking (Womack & Jones, 1996) is, nowadays, considered a philosophy based on five basic principles: 1. Value, 2. Value Stream, 3. Continuous flow, 4. Pull System and 5. Pursuit perfection. To achieve these principles and pursuit perfection, it is necessary the total involvement of everyone in the organization.

Following the thoughts of Womack and co-authors (Womack et al., 1990) many industries has been implementing Lean principles around the world (Panizzolo, 1998; Taj, 2008; Farhana & Amir, 2009; Wong et al., 2009; Silva et al., 2010; Hodge et al., 2011 and Alves et al., 2011).

3. METHODOLOGY TO IMPLEMENT LEAN IN TCI

Aware of the need of a methodology to implement LP in TCI and to discern what was already done, Maia and co-authors in Maia et al. (2011) did a literature review of methodologies to implement Lean Production. Thirteen different methodologies were reviewed:

1. TPS methodology,
2. Lean thinking,
3. Toyota way,
4. Lean automotive vision model,
5. Lean Six Sigma,
6. Kaizen methodology,
7. SECORA Lean Implementation methodology (SLIM),
8. Brief methodology,
9. Lean Alliance methodology,
10. Strategic Lean Implementation methodology (SLIM),
11. Hoshin-Kanri,
12. Methodology A3 PDCA,
13. Lean implementation model for textile industry.

From all the methodologies, it is important to highlight the thirteenth methodology, Lean implementation model for textile industry (Hodge, et al., 2011). Even so, the authors detected that none of these methodologies consider simultaneously all necessary dimensions: operational, human capital, ergonomic and sustainability to implement Lean model which must reflect the systemic nature of the companies.

The authors proposed a methodology for implementing Lean in the Textile and Clothing Industry (LPmetTCI) (Maia et al., 2012a). This methodology (Figure 1) was divided in three phases: 1) preparation of work environment and people; 2) implementation of methodology and 3) evaluation, standardization and sustainability. It considers the different dimensions referred: operational, human capital, ergonomic and sustainability to approach the overall system.

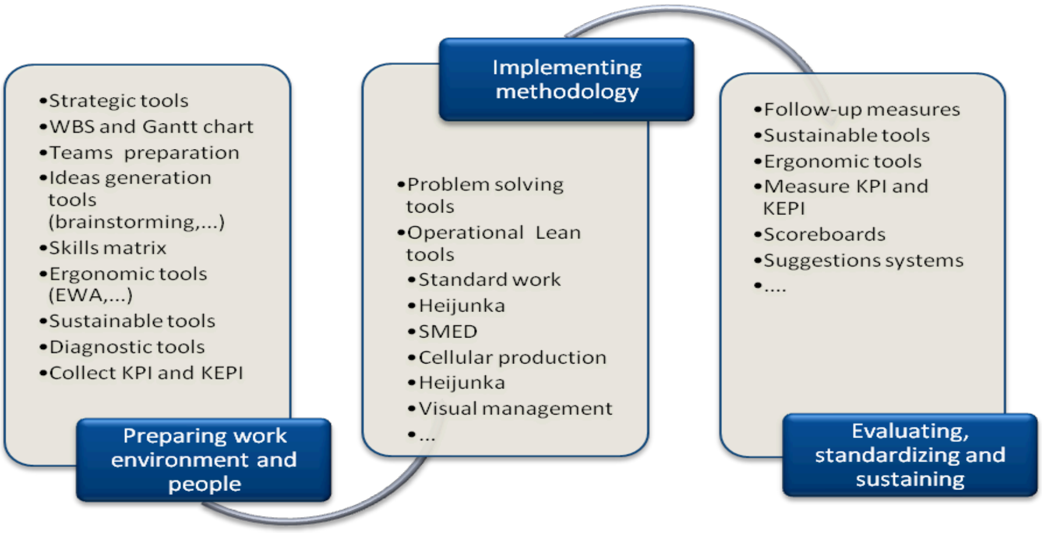

Fig.1 Framework of the methodology to implement Lean Production in TCI (Maia et al., 2012a)

As can be seen in Figure 1, the first phase of the methodology will use some ergonomic tools to diagnose and evaluate the work conditions, like the EWA (Ergonomic Workplace Analysis) (Gomes da Costa, 1995). Also, some environmental or sustainable tools will be used to evaluate the work environment.

4. ERGONOMIC RISKS AND ENVIRONMENTAL WASTES IDENTIFICATION

This section intends to identify the risks associated with ergonomic and environment in the companies of TCI. Risk can be defined, in the engineering context, as the combination of the probability of occurrence of a defined hazard and its consequence (OECD, 2010, p. 53).

4.1. Some ergonomic tools to identify ergonomic risks

According IEA (2010) Ergonomics (or human factors) *"... is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well being and overall system performance."*. 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.

Neumann (2007) aggregated in usable structure tools and methods that have been developed for work-place design and ergonomics analysis. This intended to help practitioners to select the best tool. Ergonomic tools were also reviewed and classified as checklists, qualitative, quantitative and semi-quantitative criteria in Ligeiro (2010). Maia et al. (2012b) also reviewed some tools and organize them according to the author, highlighting the factor assessed.

Briefly, these tools can be used according to the main tasks to be analyzed, namely, the Ovako Working Posture Analyzing (OWAS) (Karhu et al., 1977), Rapid Upper Limb Assessment (RULA) (McAtamney & Corlett, 1993), and Rapid Entire Body Assessment (REBA) (Hignett & McAtamney, 2000) tools for postural assessment, and in order to analyze potentially hazardous working conditions to prevent workplace injuries, namely NIOSH (1994), Occupational Safety and Health Administration risk filter (OSHA) (Silverstein, 1997) and manual checklists of International Labour Organization (ILO, 2010).

Ergonomic risks are a concern of Lean Production as Lean intends reduce the human effort. Nevertheless such implementation must involve people, so a stress free environment must be provided to the promotion of ideas and creativity (Maia et al., 2012b).

4.2. Some environmental tools to evaluate environment risks

Beyond the risks associated with the development of musculoskeletal disorders, there are risks associated to the environment, that is, the risks that are in, or transmitted through, the air, water or soil to the human being. Environmental risks come from physical, biological and chemical agent present in the work environment and that could cause harm to the worker health.

Environmental risks are also a concern of Lean Production. They are considered environmental wastes by US-EPA (2007), not always being the case (US-EPA, 2003). "*Environmental waste is an unnecessary or excess use of resources or a substance released to the air, water, or land that could harm human health or the environment. Environmental wastes can occur when companies use resources to provide products or services to customers, and/or when customers use and dispose of products"* (US-EPA, 2007, p. 2).

Examples of such wastes are: 1) energy, water, or raw materials consumed in excess of what is needed to meet customer needs; 2) pollutants and material wastes released into the environment, such as air emissions, wastewater discharges, hazardous wastes and solid wastes (trash or discarded scrap) and 3) hazardous substances that adversely affect human health or the environment during their use in production or their presence in products (US-EPA, 2007).

Such concern promotes Lean as an excellent platform to achieve sustainable development that must be in the vision and mission of all companies (Maia et al., 2012c).

The Brundtland report called "Our Common Future", define sustainable development as: "*Development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED, 1987). Sustainable development is based on three pillars: economic; environmental and social responsibility. Economically, companies must grow without compromising their integrity; socially, human rights must be respect, with social equity and social investment; environmentally, companies must worry with environment.

It is also possible to identify some environmental management tools to assess the environmental risks. Examples are: Life Cycle Management (LCM), including Life Cycle Assessment (LCA) and Life Cycle Costing (LCC), AUDIO (Aspects-Upstream-Downstream-Issues-Opportunities) analysis (Esty & Winston, 2006), design-for-environment and tools to calculate the ecological footprint. The LCC tools allow the identification of the benefits of energy efficiency design since the buildings require less equipment and consume fewer resources, and the LCA examines the process of production and determines the origin of potential harmful environmental loads.

4.3. Ergonomic risks and environmental wastes by sector of TCI

Traditionally the risks identified in TCI, according CITEVE (CITEVE, 2012) are: exposure to noise; exposure to dust; exposure to gases and vapours; exposure to inadequate lighting; transport and handling manual loads; objects projection; shock or impact; fall in height; falling objects; electric shock; crush; drag / winding; cutting / drilling / attrition; handling of chemicals and thermal environment. Figure 2 illustrates some examples of situations where these risks are present.

Fig. 2. Situations representing possible examples of risks

These risks can be both ergonomic and environmental, according to whether their impact is on human being health or human being health and environment (Figure 3). It can be seen that the environmental wastes include environmental risks.

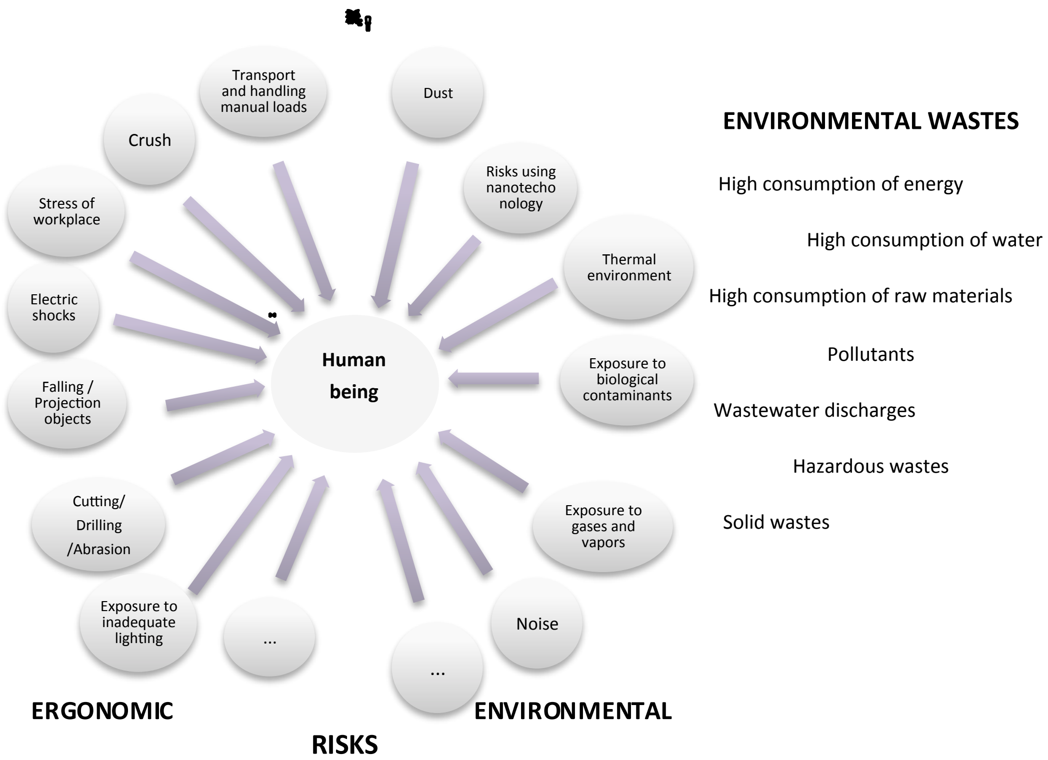

Fig. 3. Some Ergonomic risks and Environmental Wastes that have impact whether on human being and environment

Additionally, others risks were added to this list that are the stress in the workplace and risks of using nanotechnology. Today, it is unquestionable that stress in workplace is a serious health problem and nanotechnology risks, even not very well know, puts some challenges for the people and environment health (Almeida & Ramos, 2012). According CITEVE (2010) the nanotechnology risks can be classified in two ways: 1) use of products and materials with nanotechnology characteristics and 2) use of equipment and machines to produce materials that incorporate the nanotechnology.

In addition to the type of risks, they may arise according to the TCI sectors. TCI could be divided in seven different sectors: spinning, weaving, knitting, dyeing, finishing, stamping and clothing. This partition simplifies the work to identify the ergonomic risks and environmental wastes. Each sector has specific risks and wastes, according their tasks, as can be seen in table 1.

Table 1. Some ergonomic risks and environmental wastes of each sector of TCI

TCI sectors	Risks and wastes	Identified risks and wastes
Spinning	**Ergonomic**	Disrespect for ergonomics principles in workplace design, e.g., tables height and standing posture time.
	Environment	Exposure to biological contaminants (e.g., dust, dust mites,…), noise during the process and high consumption of energy.
Weaving	**Ergonomic**	Fall of heavy objects, heavy rolls of fabric, disrespect for ergonomics principles, fire or explosion and electric shocks.
	Environment	Exposure to contaminants hazardous chemicals irreplaceable, thermal stress, high consumption of energy and water and air pollution.
Knitting	**Ergonomic**	Fall of heavy objects, heavy rolls of fabric, disrespect for ergonomics principles and fire or explosion and electric shocks.
	Environment	Exposure to biological contaminants and to inadequate lighting and temperature and high consumption of energy.
Dying, Stamping, Finishing	**Ergonomic**	Disrespect for ergonomics principles, electrocution, transport and storage, working postures, very heavy loads and danger of skidding.
	Environment	Noise, exposure to contaminants hazardous chemicals irreplaceable and to inadequate lighting and temperature, biological and gases and vapours, high consumption of energy and water and air pollution.
Clothing	**Ergonomic**	Confined workspace per employee, transport and handling manual loads.
	Environment	Exposure to inadequate lighting and temperature, noise, high consumption of energy and raw-materials.

Following the textile process, beginning in spinning and ending in finishing's, it is possible to subdivide the different sectors by work areas. Spinning sector could be subdivided in three phases: 1) opening and cleaning; 2) preparation of the spinning and 3) spinning. In the first and second phase the principles risks are: dust and exposure contaminants, biological contaminants, spinning noise. In all of them it can be detected disrespect for ergonomics principles and high consumption of energy.

Weaving sector includes three phases: 1) preparation of weaving; 2) weaving and 3) review. The two first phases have critical risks like: fall of heavy objects, heavy rolls of fabric, disrespect for ergonomics, thermal stress, electric shocks, fire or explosion, electric shocks and others relates and in last phase the principal problem is eyestrain. High consumption of energy, water and air pollution are also typical environment risks of this sector.

Sector knitting is subdivided in: 1) knitting preparation; 2) knitting and 3) review. Knitting has the same ergonomics and environment risks of weaving.

The principal risks in dying, stamping and finishing, are related with the chemicals handling and storage and large amounts of water and energy consumed and also the pollution of rivers and air.

Finally clothing is divided in: 1) cutting; 2) confection and 3) finishing's and review and 4) packing. The problems in the first section are: cuts caused by the slides of cutting machines, in the in the second and fourth section are: the disrespect for ergonomics principles and monotony. Third phase is eyestrain. Environmentally there is high consumption of energy and raw-materials (caused by the high rate of defects).

Ergonomic risks can be very aggressive and painful for the workers, causing many problems and diseases that may remain for life (see table 2).

Table 2. Ergonomic risks and their consequences (adapted from CITEVE, 2012)

Ergonomic risk	Consequences
Noise	Deafness; increase in blood pressure; increased heart rate; disturbances of physical and mental abilities (irritability, sleep disturbances, loss of balance, concentration decrease, etc.); headache
Dust	Changes in respiratory function; aggravation of respiratory diseases (such as bronchitis and asthma); changes resulting from exposure to cotton dust
Exposure to gases and vapors	Changing respiratory functions; irritation of eyes, skin and respiratory system; headache; changes in the central nervous system; asphyxia; liver injury
Exposure to inadequate lighting	Eyestrain; headache; incorrect perception of reality (by strobing, poor lighting, etc..) which can cause various types of accident several types of accident; temporary loss of vision (for example by chaining)
Moving and handling charges manuals	Musculoskeletal disorders (herniated disk, sciatica, lumbago, spurs, arthritis, etc.); muscle aches; increased heart rate and blood pressure
Projection objects	Surface wounds in the skin; eye injuries
Falling objects	Surface wounds; fractures; bruising; death
Electric shock	Electrical burns; respiratory arrest; changes in heart rate; death
Crush	Surface wounds or deep; fractures; bruising; amputations
Entrainment / Winding	Surface wounds; amputations; death
Cutting/Drilling/ Abrasion	Surface wounds or deep perforations; amputations (essentially cutting - confection)
Handling of chemicals	Chemical burns; liver injury; changes in the central nervous system; carcinogenic, mutagenic or toxic for reproduction; irritation of the eyes and skin; fire and / or explosion
Thermal environment	Ddehydration; heat rash; burns; thermal fatigue; worsening of heart disease; decrease in income
Stress in the workplace	Discouragement; irritability; increased absenteeism; disturbances of physical and mental abilities (exhaustion, decreased attention)
Risks of using nanotechnology	Chemical burns; liver injury; changes in the central nervous system; carcinogenic, mutagenic or toxic for reproduction; irritation of the eyes and skin; problems with breathing (possibly aggravated due to the characteristics of nanomaterial); problems with level of bioaccumulation (associated with nanoparticles that are relatively inert, but which cannot be metabolized or excreted by the body); risks associated with the handling of machinery and equipment (shocks against objects, falling objects, falls from heights, electric shock, crushing, cutting, etc.)

5. RESULTS AND CONCLUSIONS

The musculoskeletal disorders associated to carrying or moving heavy loads or to repetitive hand and arm movements are the most common work-related health problems. However, not only the Ergonomics risks may be identified and measured but also the environmental risks and wastes must be regarded in the Textile and Clothing Industry. TCI has several problems resulting from the daily risks faced, resulting in consequences for workers (accidents diseases), some of these diseases for a lifetime. So, it is important to identify, analyse and act to minimize these risks and wastes in each sector, seeing the whole value stream of this industry. When companies are concerned with the ergonomics and the environment, they faced difficulties due to the large initial investment, to the need for the top management be committed to comply with legislation, the required involvement of all employees, the change in methodologies, practices and mentalities, the need of change or reorganize the corporate structures, the mistakes as lessons to improve, the increased training and information for employees, among others.

These difficulties could be overcome or, at least, minimized when a methodology is used since it involves and compromises the right people. During the preparation for LP implementation it is important to identify these risks and wastes and difficulties since a lot of problems can be avoided if they are known right on the first step and in order to better prepare the work environment to the LP implementation.

ACKNOWLEDGMENTS

The authors are grateful to Portuguese Foundation for Science and Technology, under Strategic Projects PEst-OE/EME/UI0252/2011 and PEst-C/EEI/UI0319/2011, for financial support.

REFERENCES

Almeida, L. & Ramos. D. (2012). Nanotechnologies are safe? New demand for standardization. Proceedings of International Symposium on Occupational Safety and Hygiene (SHO2012), 9-10 February, Guimarães, Portugal.

Alves, A. C.; Carvalho, D.; Sousa, R.; Moreira, F. & Lima, R. (2011) "Benefits of Lean Management: results from some industrial cases in Portugal", Proceedings do 6º Congresso Luso-Moçambicano de Engenharia (CLME2011), 29 Agosto-2 de Setembro, Maputo, Moçambique

Bicheno, J. (2008). The Lean Toolbox for Service Systems. PICSIE Books.

CITEVE - Centro Tecnológico Têxtil e Vestuário (2012) Plano de ação setorial da melhoria das condições de higiene e segurança no trabalho no setor têxtil e do vestuário

Esty, D.C. and Winston, A.S. (2006). Do verde ao ouro. Tradução de R. Fidalgo, Casa das Letras.

Farhana F., Amir A. (2009). Lean production practice: the differences and similarities in performance between the companies of Bangladesh and other countries of the world. Asian Journal of Business Management. Vol. 1, No. 1, 32–36.

Gomes da Costa (1995). Estudo Ergonómico de Postos de Trabalho. Universidade do Minho, Escola de Engenharia. (Translated from EWA of Ergonomics Section, Finish Institute of Occupational Health (FIOH), Ergonomic Workplace Analysis, 1989).

Heston, T. (2006). Ergonomics is the first step to Lean. from: http://www.fabricatingandmetalworking.com/2006/07/ ergonomics-the-first-step-to-lean/, accessed on 2011-12-05

Hignett, S. & McAtamney, L. (2000). Rapid Entire Body Assessment (REBA). Applied ergonomics, n. 31, p. 201-105.

Hodge, G.L., Goforth, K.R., Joines, J.A. and Thoney, K. (2011). Adapting lean manufacturing principles to the textile industry. Production Planning & Control, Vol. 22, No 3, 237–247.

IEA – International Ergonomics Association. (2011). Definition of ergonomics, from: http://www.iea.cc, accessed on 2011-11-25.

ILO – International Labour Office (2010). Ergonomic checkpoints: Practical and easy-to-implement solutions for improving safety, health and working conditions. International Labour Organization

Karhu, O., Kansi, P., & Kuorinka I. (1977). Correcting working postures in industry: a practical method for analysis. Applied Ergonomics, v. 8, n. 4, p. 199-201

Ligeiro, J. (2010). Ferramentas de avaliação ergonômica em atividades multifuncionais: a contribuição da ergonomia para o design de ambientes de trabalho. Universidade Estadual Paulista Júlio de Mesquita Faculdade de Artes, Arquitetura e Comunicação programa de pós-graduação em Design.

Liker, J. K. (2004). The Toyota Way: 14 Management Principles From the World's Greatest

Maia, L. C., Alves, A. C. & Leão, C. P. (2012a). Design of a Lean Methodology for an ergonomic and sustainable work environment in textile and garment industry. Proceedings of the ASME 2012 International Mechanical Engineering Congress & Exposition - IMECE2012 November 9-15, 2012, Houston, Texas, USA.

Maia, L. C., Alves, A. C. & Leão, C. P. (2012b). Do Lean Methodologies include ergonomic tools? In Proceedings of International Symposium on Occupational Safety and Hygiene (SHO2012), pp.350-356. http://hdl.handle.net/1822/18877.

Maia, L. C., Alves, A. C. & Leão, C. P. (2012c). Sustainable Work Environment with Lean Production in Textile and Garment Industry. In Proceedings of International Conference on Industrial Engineering and Operations Management (ICIEOM2012), (Eds.) R. M. Lima, D. Carvalho, V. Cavenaghi, M. V. Junior, G. L. R. Vaccaro, R. F. M. Marçal, F. S. Másculo, L. F. R. R. S. Carmo, ISBN: 978-85-88478-43-5

Maia, L. C., Alves, A. C. and Leão, C. P. (2011). Metodologias para implementar Lean Production: uma revisão crítica de literatura. (Methodologies to implement Lean production: a critical review of literature). Proceedings of 6º Congresso Luso-Moçambicano de Engenharia (CLME2011), 29 Agosto-2 de Setembro, Maputo, Moçambique (in Portuguese).

McAtamney, L. Corlett, E. (1993). RULA: Rapid upper limb assessment – A survey method for the investigation of work-related upper limb disorders. Applied Ergonomics. 24:2, 91-99.

Monden, Y. (1983). Toyota Production System. Industrial Engineering and Management Press, Institute of Industrial Engineers.

Neumann, W. P. 2007. Inventory of Human Factors Tools and Methods: A Work-System Design Perspective. (Ed.), Ryerson University, Beta v2.0.0 – Available at: http://www.ryerson.ca/hfe/, accessed at: 2013.03.14.

NIOSH - National Institute for Occupational Safety and Health (1994). Applications manual for the revised NIOSH lifting equation. U.S. Dept. of Health and Human Services (NIOSH), Public health Service, Cincinnati, OH.

OECD (2010). Risk and Regulatory Policy: Improving the Governance of Risk. OECD Publishing. doi: 10.1787/9789264082939-en

Ohno, T. (1988). The Toyota Production System: beyond large-scale production. Productivity Press.

Panizzolo R. (1998). Applying the lessons learned from 27 lean manufacturers: The relevance of relationships management. International Journal of Production Economics 1998. 55 (3), 223-240.

Silva, C., Tantardini, M., Staudacher, A., P. & Salviano, K. (2010). Lean Production Implementation: A survey in Portugal and a comparison of results with Italian, UK and USA companies, In Proceedings of 17th International Annual EurOMA Conference-Managing Operations in Service Economics, (Eds.) R. Sousa, C. Portela, S. S. Pinto, H. Correia, Universidade Católica Portuguesa, 6-9 June, Porto, Portugal.

Silverstein, B. (1997). The use of checklist for upper limb risk assessment. Congress Tampére, 13, 1997. Proceedings… Tampére: International Ergonomics Association.

Taj, S. (2008). Lean manufacturing performance in China: assessment of 65 manufacturing plants. Journal of Manufacturing Technology Management. 19(2). 217-234.

U.S.-EPA (2003). Lean manufacturing and the environment: Research on advanced manufacturing systems and the environment and recommendations for leveraging better environmental performance. United States Environmental Protection Agency.

U.S.-EPA (2007). The Lean and Environment Toolkit. United States Environmental Protection Agency, available from: http://www.epa.gov/lean/environment/toolkits/environment/resources/LeanEnviroToolkit.pdf, [accessed 21 February, 2012].

WCED (1987). Our Common Future. Report of the World Commission on Environment and Development, United Nations. Available from: http://worldinbalance.net/intagreements/1987-brundtland.php [accessed 16 February 2012].

Womack, J.P. & Jones, D.T. (1996). Lean Thinking – Banish waste and create wealth in your corporation. Siman & Schuster, UK.

Womack, J.P., Jones, D.T. & Roos, D. (1990). The machine that changes the world: The story of Lean Production. Rawson Associates, NY.

Wong, Y.C., Wong, K.Y., Ali, A. (2009). A Study on Lean Manufacturing Implementation in the Malaysian Electrical and Electronics Industry. European Journal of Scientific Research. Vol. 38, No. 4, 521–535.