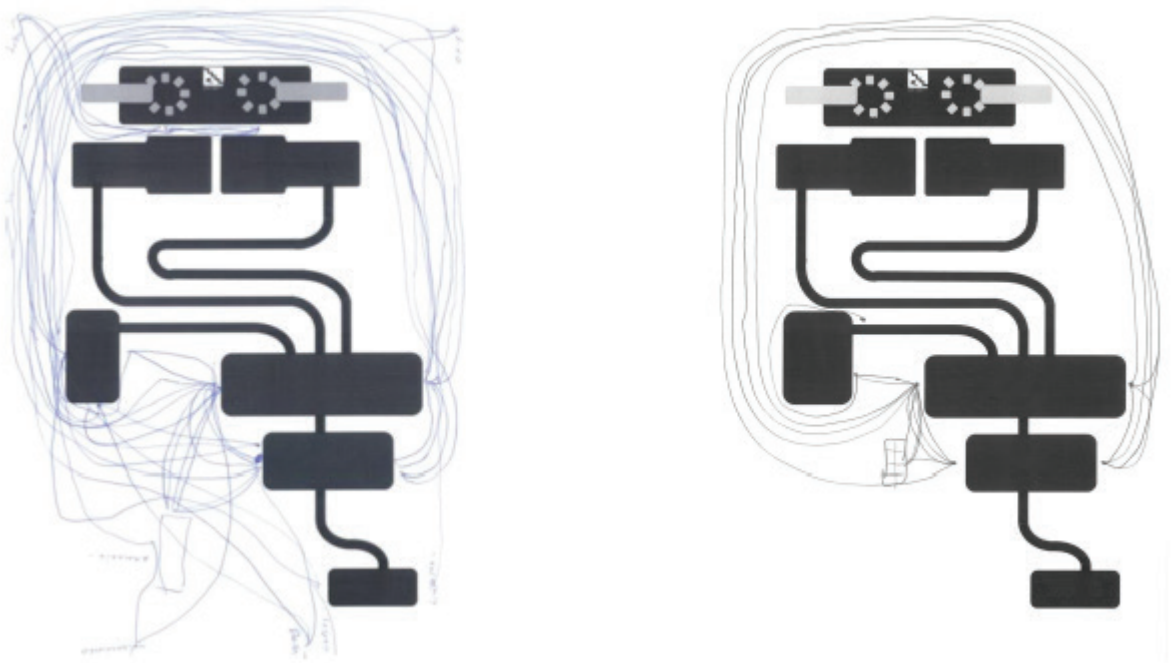

Figure 4. Spaghetti diagram in lines 4/5 before (left) and after SMED (right).

Once standards were defined, the SMED implementation according to Shingo (1985) ensued. The "separate" stage enabled classifying tasks as internal or external, grouped afterwards. In these changeovers run-down and run-up times were extremely short and therefore it was not found useful to differentiate them. Then, in the second stage, on average 8, 11, 3 and 10 tasks respectively for lines 1, 2, 3 and 4/5 were converted into external. These were mostly tasks intending fetching/storing materials for performing the changeover, making small tests to the product, and cleaning the machine or the workspace. In "streamline", tasks were attempted improving by using dedicated movable workbenches and visual management for showing recommended actions. Additionally, there were some equipment design improvements on the packaging lines and on measurement tools, the latter being the one providing the largest time reductions.

Table 5 shows average values of number of tasks and changeover duration before and after SMED implementation, time reductions were in the range 23-45%. A (conservative) estimate points to savings of 100.000 Euros/year just from this increase in productivity. SMED was applied in the following order: line 3, lines 4/5, line 2, and line 1. Interestingly, the success of the first implementation was already known in the following, to the point where operators were highly motivated into reaching the same level of success in their respective lines.

	Line 1		Line 2		Line 3		Lines 4/5	
	# Tasks	Time	# Tasks	Time	# Tasks	Time	# Tasks	Time
Before SMED	25	00:36:40	27	00:46:48	30	00:52:43	30	00:43:20
Total internal after SMED	17	00:20:00	16	00:27:54	27	00:35:00	20	00:33:20
Improvement		45.45%		40.38%		33.61%		23.08%

Table 5. Average number of tasks and times per changeover before and after SMED.

Based on past experience, it was considered important to perform regular audits on changeover operations for ensuring standardized work is adhered to. After several months audit results and collected data showed that changeover times were indeed reduced and best practices were still being followed. The difference considered having the biggest impact between these implementations and the ones performed previously in lines 8 and 9 (which failed to meet objectives) was that all employees were now part of the implementation team and their feedback and suggestions were highly valued.

Conclusions

In the last decades lean has been a major catalyst for organizational and process innovation in manufacturing companies. Despite successful applications being reported in several industrial sectors, concerning food and beverage industries these have been lacking. The characteristics of these sectors may have led to resistance in changing companies' practices and embracing new management philosophies such as LM.

This work presents two case studies of companies of the food and beverage industries which have experienced successful LM applications. For the reported cases, several improvements could be found on implementing LM principles and tools, extending even beyond direct gains in productivity, e.g., improving production flexibility, increasing employee engagement, and motivating a continuous improvement culture. Based on these results, it can be concluded that this management philosophy can also be applied to these sectors making information in this paper of interest to general food and beverage manufacturers, particularly medium and large sized companies.

Moreover, this work reinforces employee engagement and empowerment as critical to the success of lean implementations. In one of the case studies it was considered the main driver, as was the main difference to a previously failed application of SMED. Therefore, even though technical aspects are relevant and drivers for an initial process innovation using lean tools (techniques used in the presented case studies seem to more easily identify issues and/or help solving them) for maintaining process innovations employee engagement is critical.

As future work, a follow up on the level of lean implementation and cultural change in the companies addressed in this study is advised. Also, specifically concerning SMED, future work may focus on more accurately quantifying the impact of machine design changes and the impact in inventory reduction. Finally, another interesting research avenue may be comparing LM implementation results among companies of different sectors. This would allow further understanding the potential and importance of process innovation in different industrial contexts.

Acknowledgements

This work was supported by Portuguese funds through the CIDMA – Center for Research and Development in Mathematics and Applications, and the Portuguese Foundation for Science and Technology ("FCT – Fundação para a Ciência e a Tecnologia"), within project PEst-OE/MAT/UI4106/2014.

References

Bayo-Moriones, A., Bello-Pintado, A., & Cerio, J. M. D. (2010). 5S use in manufacturing plants: Contextual factors and impact on operating performance. *International Journal of Quality & Reliability Management*, 27, 217-230. doi: 10.1108/02656711011014320

Boston Consulting Group (2015). Lean food-and-beverage manufacturing: Lower costs, better products, improved sustainability. Retrieved June 20, 2015, from http://www.bcg.com/documents/file49085.pdf

Cakmakci, M. (2008). Process improvement: Performance analysis of the setup time reduction-SMED in the automobile industry. *The International Journal of Advanced Manufacturing Technology*, 41, 168-179. doi: 10.1007/s00170-008-1434-4

Chapman, C. D. (2005). Clean house with lean 5S. *Quality Progress*, 38, 27-32.

Coimbra, E. A. (2009). *Total flow management: Achieving excellence with kaizen and lean supply chains*. Zug: Kaizen Institute.

Courtois, A., Martin-Bonnefous, C., & Pillet, M. (2007). *Gestão da produção: Para uma gestão industrial ágil, criativa e cooperante*. Lisboa: Lidel.

Cox, A., & Chicksand, D. (2005). The limits of lean management thinking: Multiple retailers and food and farming supply chains. *European Management Journal*, 23, 648-662. doi: 10.1016/j.emj.2005.10.010

Davenport, T. H. (1993). *Process innovation: Reengineering work through information technology*. Harvard Business Review Press.

Dennis, P. (2007). *Lean production simplified*. New York: Productivity Press.

Dora, M., Goubergen, D. V., Kumar, M., Molnar, A., & Gellynck, X. (2014). Application of lean practices in small and medium-sized food enterprises. *British Food Journal*, 116, 125-141. doi: 10.1108/BFJ-05-2012-0107

Dudbridge, M. (2011). *Handbook of lean manufacturing in the food industry*. Chichester: Wiley-Blackwell.

Ferradás, P. G., & Salonitis, K. (2013). Improving changeover time: A tailored SMED approach for welding cells. *Procedia CIRP*, 7, 598-603. doi: 10.1016/j.procir.2013.06.039

Gapp, R., Fisher, R., & Kobayashi, K. (2008). Implementing 5S within a Japanese context: An integrated management system. *Management Decision*, 46, 565-579. doi: 10.1108/00251740810865067

Gest, G., Culley, S. J., McIntosh, R. I., Mileham, A. R., & Owen, G. W. (1995). Review of fast tool change systems. *Computer Integrated Manufacturing Systems*, 8, 205-210. doi: 10.1016/0951-5240(95)00011-H

George, M. L. (2003). *Lean six sigma for service: How to use lean speed and six sigma quality to improve services and transactions*. McGraw-Hill.

Henry, J. R. (2012). *Achieving lean changeover: Putting SMED to work*. Boca Raton, FL: Productivity Press.

Heymans, B. (2015). Lean manufacturing and the food industry. Retrieved June 5, 2015, from http://www.flowmakers.com/articles/Articlefoodindustryandkaizen.pdf

Hirano, H. (1996). *5S for operators: 5 pillars of the visual workplace*. Portland: Productivity Press.

Hirano, H. (2009). *JIT implementation manual – The complete guide to just-in-time manufacturing: Volume 2 – Waste and the 5S's*. New York: Productivity Press.

Hodge, G. L., Ross, K. G., Joines, J. A., & Thoney, K. (2011). Adapting lean manufacturing principles to the textile industry. *Production Planning & Control*, 22, 237-247. doi: 10.1080/09537287.2010.498577

Holden, R. J. (2011). Lean thinking in emergency departments: A critical review. *Annals of Emergency Medicine*, 57, 265-278. doi: 10.1016/j.annemergmed.2010.08.001

Kennedy, I., Plunkett, A., & Haider, J. (2013). Implementation of lean principles in a food manufacturing company. In A. Azevedo (Ed.), *Advances in Sustainable and Competitive Manufacturing Systems*, *Lecture Notes in Mechanical Engineering* (pp. 1579-1590). Springer. doi: 10.1007/978-3-319-00557-7_127

Kumar, M., Antony, J., Singh, R. K., Tiwari, M. K., & Perry, D. (2006). Implementing the lean sigma framework in an Indian SME: A case study. *Production Planning & Control*, 17, 407-423. doi: 10.1080/09537280500483350

Mahalik, N. P., & Nambiar, A. N. (2010). Trends in food packaging and manufacturing systems and technology. *Trends in Food Science & Technology*, 21, 117-128. doi: 10.1016/j.tifs.2009.12.006

Marodin, G. A., & Saurin, T. A. (2013). Implementing lean production systems: Research areas and opportunities for future studies. *International Journal of Production Research*, 51, 6663-6680. doi: 10.1080/00207543.2013.826831

McIntosh, R., Owen, G., Culley, S., & Mileham, T. (2007). Changeover improvement: Reinterpreting Shingo's "SMED" methodology. *IEEE Transactions on Engineering Management*, 54, 98-111. doi: 10.1109/TEM.2006.889070

Mika, G. (2006). *Kaizen event implementation manual, 5th edition*. Dearborn, MI: Society of Manufacturing Engineers.

Moreira, A. C., & Pais, G. C. S. (2011). Single minute exchange of die. A case study implementation. *Journal of Technology Management & Innovation*, 6, 129-146. doi: 10.4067/S0718-27242011000100011

OECD (2005). *OSLO manual, guidelines for collecting and interpreting innovation data, 3rd Edition*. OECD.

Patel, V. C., & Thakkar, H. (2014). Review on implementation of 5S in various organization. *International Journal of Engineering Research and Applications*, 4, 774-779.

Pearce, A., & Pons, D. (2013). Implementing lean practices: Managing the transformation risks. *Journal of Industrial Engineering*, 2013, 19 pages. doi: 10.1155/2013/790291

Shingo, S. (1985). *A revolution in manufacturing: The SMED system*. Cambridge, MA: Productivity Press.

Simons, D., & Zokaei, K. (2005). Application of lean paradigm in red meat processing. *British Food Journal*, 107, 192-211. doi: 10.1108/00070700510589495

Sousa, R., & Voss, C. A. (2008). Contingency research in operations management practices. *Journal of Operations Management*, 26, 697-713. doi: 10.1016/j.jom.2008.06.001

Thun, J. H., & Hoenig, D. (2011). An empirical analysis of supply chain risk management in the German automotive industry. *International Journal of Production Economics*, 131, 242-249. doi: 10.1016/j.ijpe.2009.10.010

Utterback, J. M., & Abernathy, W. J. (1975). A dynamic model of process and product innovation. *Omega*, 3, 639-656. doi: 10.1016/0305-0483(75)90068-7

Vlajic, J. V., Vorst, J. G. A. J., & Haijema, R. (2012). A framework for designing robust food supply chains. *International Journal of Production Economics*, 137, 176-189. doi: 10.1016/j.ijpe.2011.11.026

Womack, J. P., Jones, D. T., & Ross, D. (1990). *The machine that changed the world*. London: Macmillan.

Yin, R. K. (2014). *Case study research: Design and methods*. Sage publications.