6 Conclusion and Future work

Lean manufacturing has been extensively used to identify and eliminate waste in industrial facilities. The application of VSM in conjunction with the 5 whys technique and other quality control techniques may resulted in savings in material and energy in steel plants. The proposed methodology results in identifying the main causes of losses and thus may help in saving 0.56 % of total monthly production from the lost billets as a result of cobbles that occur at one of the most critical locations in the rolling line. Furthermore, a potential saving of 26.9% of natural gas consumption, an increase in production by 7.58%, and a decrease in stoppage time may be achieved. These results obtained by recommended actions between 2 guides only. By applying the same approach to other rolling guides, additional savings are expected. The approach is data-driven, yet no extra data collection is needed, it relies on data collected for production and quality control which is readily available. The future work is to extend the value stream map to account for all types of energy and water consumption.

References

Aadithya, G. Application of Energy Value Stream Mapping as Auditing Tool for Non-Value Added Industrial Energy Management, *Proceedings of the 3rd International Conference on Electrical Energy Systems (ICEES)*, Chennai, India, 17-19 March, 2016.

Bhamu, J. and Sangwan, K. S., Lean manufacturing: Literature review and research issues, *International Journal of Operations and Production Management*, vol. 34, no. 7. pp. 876–940, 2014.

Cudney, E. and Elrod, C., A Comparative Analysis of Integrating Lean Concepts into Supply Chain Management in Manufacturing and Service Industries, *International Journal of Lean Six Sigma*, vol. 2, no. 1, pp. 5–22, 2011.

Cheung, W. M., Leong, J. T. and Vichare, P., Incorporating lean thinking and life cycle assessment to reduce environmental impacts of plastic injection moulded products, *J. Clean. Prod.*, vol. 167, pp. 759–775, 2017.

Davim, J. P.(Editor), *Progress in Lean Manufacturing*, Springer International Publishing AG, part of Springer Nature, 2018.

Khaba, S. and Bhar, C., Lean Awareness and Potential for Lean Implementation in the Indian Coal Mining Industry: An Empirical Study, *International Journal of Quality and Reliability Management*, vol. 35, no. 6, pp. 1215–1231, 2018.

Kumar, S., Dhingra, A. and Singh, B., Lean-Kaizen implementation: A roadmap for identifying continuous improvement opportunities in Indian small and medium sized enterprise, *Journal of Engineering, Design and Technology*, vol. 16, no. 1, pp. 143–160, 2018.

Oliveira, J., Sá, J. C., and Fernandes, A., Continuous improvement through 'Lean Tools': An application in a mechanical company, *Procedia Manufacturing*, vol. 13, pp. 1082–1089, 2017.

Rocha, D. V., Lean manufacturing applied in a large company in the Brazilian steel Industry, *Proceedings of the Production and Operations Management Society (POMS) 25th* Annual *Conference*, Atlanta, GA, USA, 9-12 May, 2014.

Saraswat, P., Kumar, D. and Sain, M.K., Reduction of Work in Process Inventory and Production Lead Time in a Bearing Industry using Value Stream Mapping Tool, *International Journal of Managing Value and Supply Chains (IJMVSC)*, vol. 6, no.2, pp.27–35, 2015.

Verma, N. and Sharma, V., Energy value stream mapping a tool to develop green manufacturing, Procedia Engineering, vol. 149, pp. 526–534, 2016.

Wickramasinghe, G. L. D. and Wickramasinghe, V., Implementation of lean production practices and manufacturing performance: The role of lean duration, *Journal of Manufacturing Technology Management*, vol. 28, no. 4. pp. 531–550, 2017.

Worldsteel (2018), *Steel Statistical Yearbook*, Available: https://www.worldsteel.org/steel-by-topic/statistics/steel-statistical-yearbook-.html, March 28, 2018.

Zuraidah, R., Abdullah, R. and Mohamed, S., Value stream mapping using simulation at metal manufacturing industry, Proceedings of the 2014 International Conference on Industrial Engineering and Operations Management, Bali, Indonesia, January 7 – 9, 2014.