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Todorut, Amalia Venera and Paliu-Popa, Lucia and Tselentis, V S and Cirnu, Doru

Constantin Brancusi University of Targu Jiu

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A.V. TODORUT, L. PALIU-POPA, V. S. TSELENTIS, D. CIRNU

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This paper focuses on the need for sustainable cost reduction in the metallurgical industry by applying Lean Management (LM) tools and concepts in metallurgical production processes leading to increased competitiveness of corporations in a global market. The paper highlights that Lean Management is a novel way of thinking, adapting to change, reducing waste and continuous improvement, leading to sustainable development of companies in the metallurgical industry. The authors outline the main Lean Management instruments based on recent scientific research and include a comparative analysis of other tools, such as Sort, Straighten, Shine, Standardize, Sustain (5S), Visual Management (VM), Kaizen, Total Productive Maintenance (TPM), Single-Minute Exchange of Dies (SMED), leading to a critical appraisal of their application in the metallurgical industry.

Key words: metallurgical processes, Lean Management, sustainability, cost reduction, market

INTRODUCTION

The metallurgical industry, as a multiplier of added value and job generator, is part of a series of industrial value chains and is closely linked to many industries, such as the automotive, construction, energy, electronics, mechanical and electrical engineering. A brief characterization of the metallurgical industry reveals a significant characteristic with implications on the sustainability of the activity related to the costs of production. These record high values, especially due to the price of raw materials which have been constantly increasing as a result of the high complexity and energy requirements of the manufacturing processes.

Metallurgical enterprises are unable to reduce the price of raw materials and of inputs in general, and therefore cost reduction is a viable opportunity for companies in the field to remain competitive within a global scale. A sample framework for the sustainable cost reduction has been outlined [1] and structured in three stages: Quick victories – characterized by immediate identification of cost reduction opportunities based on past experience; Optimization – involving a more efficient deployment of current processes by improving the business processes, reducing and eliminating the activities that do not bring new value and reducing the average unitary prices; Sustainability – cultural and operational changes through focusing on a more efficient and effective operating model, based on continuous, fluent and rational processes, which reduce the operating cost per ton of product, i.e. steel. Innovative strategies underlie these processes through the integration of modern methods of cost reduction in the day to day management of the enterprise. Metallurgical companies

A.V. Todoruţ, "Constantin Brancusi" University of Targu Jiu, Faculty of Education Science and Public Management, Targu Jiu, Romania, L. Paliu-Popa, "Constantin Brancusi" University of Targu Jiu, Faculty of Economics, Targu Jiu, Romania, V.S. Tselentis, University of Piraeus, Greece, D. Cirnu, "Constantin Brancusi" University of Targu Jiu, Faculty of Economics, Targu Jiu, Romania.

must therefore reconsider and renew their business models by relying on a rigorous analysis which enables the identification of processes that create waste and inefficiency, establish the root causes and elaborate the steps for continuous improvement.

RESEARCH METHODOLOGY

The method used for investigating the existing situation and characteristics of the steel industry was based on the analysis of documents including scientific papers in the specific literature dedicated to sustainable cost reduction, government reports, studies and articles by agencies linked to state authorities and enterprises, as well as analytical reports and studies about managerial methodologies. The present paper, in particular, analyses the potential sustainable cost reduction in steel manufacturing companies, by modern methodologies, such as LM. The research conducted also examines the feasibility of applying modern and integrative methods for improving the process in steel companies. This novel approach proves to have many advantages and improves manufacturing processes, which, must rise up to the challenges posed by modern day structural and operational challenges. Some of the research directions were also designed to address problems of competitiveness through the lean optimization of the value chain of the metallurgical enterprise. This study proposes a new vision of lean production, indicating that the implementation of lean standards could be an opportunity that leads to sustainable improvements and position metallurgical companies for high performance.

COST OPTIMIZATION

For companies seeking to get a sustainable decrease in costs, the optimization of key processes is essential.

In this context, we propose the LM approach, based on continuous improvement, as a cost-saving solution, focused on methods to reduce costs without compromising safety, environmental sustainability and capital budgets.

Following the deployment of excellent processes through specific instruments and methodologies, the metallurgical companies can make rapid progress towards measurable improvements.

An initial analysis involves identifying

Table 1 **List of opportunity levers to drive down costs [1]**

Cost	Opportunity levers	Cost / %
Raw materials	- Evaluate cost per unit of raw materials based on actual value in use; - Improve process for handling scrap; - Increase reutilization of slag and sludge; - Manage yield losses through the production flow; - Improve accuracy of alloy additions.	80 - 90
Operation	- Evaluate cost vs. life refractory; - Decrease variability of activities through: automation, improve process control (loop tuning, decrease operator variability through standard procedures); - Resolve trade-offs between manufacturing efficiency (length of runs) and customer service; - Define roadmap to implement new technology.	2 - 3
Maintenance	- Define and execute standard maintenance procedures such as preventive or productive maintenance practices; - Improve ability to track, investigate and address root causes for unplanned outages; - Optimize inventory of spare parts to balance between cost and response time to equipment failures; - Resolve trade-offs between equipment replacements vs. rebuild.	4 - 5
Energy	- Enhance the use of recovery gases in coke ovens and blast furnaces; - Improve heat containment by reducing convection and radiation losses; - Optimize energy consumption through advanced process control looping.	1 - 2
Labour	- Implement a system for performance based on incentives; - Evaluate use of contracted services based on total cost; - Balance size and number of labour crews against cost of overtime.	2 - 3

Key Value Levers that can be used in reducing operating costs and achieving sustainable performance. Some of them are listed in Table 1, together with a potential range of opportunities for improvement.

Cost reduction and its optimization require the elimination of any unnecessary practice that does not add value to the process. Thus, the management of flow values is a way of concentrating all efforts towards achieving the appropriate objectives by allocating the resources for those activities which bring new value.

THE LM ARCHITECTURE IN METALLURGICAL PROCESSES

Lean architecture is structured on the main Lean instruments which can also be applied in the metallurgical industry: 5S, VM, Kaizen, TPM, SMED.

The 5S System is a methodology to create and maintain an organized, clean, efficient and safe work environment. 5S refers to five particular activities [2] which are: sorting, ordering, shine, standardization and support. The 5S method also has its place and use in metallurgical enterprises, especially in identifying positions, transportation routes, safety signs in buildings for the protection of workers and marking of the exact location of individual tools. VM is a concept which supports the application of LM, since it encompasses a self-ordering, self-explaining and in a sense, self-regulating workplace, leading to a self-improving niche in which processes materialise as planned with regard to time, sequence and causality, due to the use of visual solutions [3]. In the production side of the metallurgical industry several applications have proven to be highly successful, such as upper and lower limits being clearly marked on important measuring devices such as thermometers, pressure gauges, carbon monoxide levels, particulate matter etc. These functionaries make the indicators sufficiently clear so as to avoid confusion. Clearly these simple but highly important functionaries contribute to efficiency, and improved working condition [4]. Further to the above principle, LM also strives to systematically eliminate waste and establish a thorough and comprehensive problem solving methodology LM aspires to following these highlights with a well thought-out and integrated methodology in order to identify causative factors with subsequent problem solving. In addition the Kaizen strategy is the continuous improvement strategy and aims at developing a gradual, continuous improvement of the processes as well as the quality of services productivity and competitiveness with the participation of all staff [5]. The Kaizen philosophy can be summarised as the process in which increased vigilance and investigation makes the process clear and understandable while the proposed improvements will be achieved through the elimination of waste and the application of sustainable practices. The necessity for metallurgical enterprises to search for these possible ways of cost reduction and to apply or improve existing ones, based on the above LM principles is a highly recommendable approach. In this process it is imperative to involve every employee, regardless of their position at work, since it is possible to look for savings in all areas of the production process, starting from the company management and up to the actual production [6]. TPM uses 5 basic activities to eliminate stoppage of production facilities and consequent loss of productivity and increased costs: This is achieved by applying and maintaining optimal conditions for the operation of the equipment, compliance with the prescribed operating conditions, early diagnosis of faulty parts and repair of damaged parts, a comprehensive stock of spare parts most commonly used, elimination of imperfections in equipment design and finally, improving worker's skills and know-how. For metallurgical enterprises, and blast furnaces in particular, the TPM approach is applicable only to a certain extent, since metallurgical processes are mostly of continuous flow. However, more extensive application of TPM can be found in follow-up processes, such as moulding, rolling and treatment of steel products. In these areas, workers can perform small maintenance interventions and implement a risk assessment and management of equipment damage including an inventory of spare parts [7]. Finally, SMED is a system for dramatically reducing the time it takes to complete equipment changeovers. The essence of the SMED approach is to convert as many changeover steps as possible to “external” (performed while the equipment is running), and to simplify and streamline the remaining steps. The application of SMED in the metallurgical industry cannot be easily applied in the production of iron such as casting, but has many application possibilities in the follow-up processes, such as moulding, rolling and other machining operations, especially in case of equipment capable of producing various ranges of products, such as laser cladding, lathes, milling machines, and drills. Several applications have been described using the above processes including the use of guillotines, gas cutters, bending and welding apparatus [8].

CONCLUSIONS

It is known that companies in the metallurgical industry have low levels of LM implementation. Each enterprise may carry out several different actions that prove insufficient to contribute to a sustainable cost reduction through optimization. We are currently witnessing the development of more and more sophisticated operating models involving new organizational structures, new processes of business, new methods and managerial tools that allow companies in the metallurgical industry to be more efficient and achieve a sustainable competitive advantage in an increasingly aggressive market. The lean concepts, besides the automotive industry, can be applied in the foundry industry, bringing benefits of better productivity and making the production flowing. LM is based on the principle of flexibility and the rapidity of response to the request for products or services and aims at increasing the efficiency of the whole process chain that creates added value to products or services.

LM is a successful production model which leads to increased productivity and competitiveness for a company because it allows the cost reduction and increased profits through establishing discipline and rigor in carrying out the company’s activities.

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