

APPLICATION OF SELECTED LEAN MANUFACTURING (LM) TOOLS FOR THE IMPROVEMENT OF WORK SAFETY IN THE STEEL INDUSTRY

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This article presents the possibilities of the application of Lean Manufacturing (LM) tools for the improvement of occupational safety and health. The issue of work safety in the steel industry is of particular relevance for the management of steelworks due to the number of recorded accidents at work. Given the above, the most common causes of accidents at work in the steel industry in Poland in 2009-2019 were listed. Their analysis made it possible to propose a possibility to implement solutions provided for within the Lean Manufacturing concept. This article aims to consider the possibility of adapting LM tools in order to address the causes of accidents at work and improve work safety in enterprises in the metallurgical sector.

Key words: steel industry, work safety, accident, lean manufacturing tools, Poland

INTRODUCTION

Occupational safety and health constitutes an essential element of the functioning of enterprises in the metallurgical sector. Employers should therefore take measures aimed at reducing accidents at work, as they generate social and economic costs for steel enterprises [1,2]. Effective action in this respect will require the identification of occupational risks that include, among others, vibrations, broadband noise, radiation, high temperatures, dusts, fumes, vapors, gaseous substances [3,4], as well as numerous other factors that may be dangerous or harmful to health.

In Polish legislation, the Regulation on the occupational safety and health in the steel industry [5] lays down the occupational safety health (OSH) rules to be met by metallurgical plants in Poland. The Regulation [5] indicates the types of occupational risks and the employer's obligation to reduce them.

Such an analysis allows for the selection and implementation of preventive solutions aimed at reducing and eliminating the occurrence of similar events in future. Therefore, this study identifies the most common causes of accidents at work and proposes the implementation of methods and tools of Lean Manufacturing concept by which the metallurgical sector may significantly improve work safety.

LM is a production system developed by Toyota Motor Company that is now widely used by manufacturers worldwide. Production in this system is described as lean because it uses fewer resources compared to

mass production in twice as short a period of time [6]. The primary aim of the LM concept is to eliminate activities that do not bring added value to the processes. The concept offers many effective methods and tools which, if properly selected, implemented and used by steel enterprises, can produce the expected results such as the elimination of errors and quality defects, increase in productivity, and they may contribute to improving work safety and ergonomics. LM tools essential for the improvement of OSH in the steel industry include [7]: workplace organization (5S/6S method), visual management (VM), Kaizen, Autonomous Maintenance (AM), Single Minute Exchange of Die (SMED), standardization of work (SoW), one point lesson (OPL).

METHODOLOGY

A three-stage methodology was developed to achieve the objective pursued in this study consisting in the adaptation of LM tools in the area of work safety improvement in enterprises in the steel industry.

The first stage involved the identification of the causes of accidents at work in 2009-2019 – statistical data [8]. The listed causes were deficiencies and irregularities that directly or indirectly contributed to an accident. They were related to material factors, work organization or organization of work stations and also included employees' behavior.

The second stage consisted in the identification of LM tools that take into account employees' behavior and whose scope includes technical and organizational solutions. The impact of a given tool on reducing the cause of an accidental event was assumed by convention for selected LM tools. High impact on reducing the cause of an accidental event was marked as (+++), medium impact (++) , and low impact (+). The impact is understood to be

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a subjective interpretation of the effect of a given tool on reducing the causes of accidents at work.

The third stage involved a selection of tools with a high impact and the most frequent repeatability in reducing the causes of accidents at work in the steel sector in Poland.

IDENTIFICATION OF THE CAUSES OF ACCIDENT AT WORK AND SELECTION OF LM TOOLS

The identification of the causes of accidents at work in the steel sector in Poland was carried out using data released by Statistics Poland [8]. The compiled statistical data made it possible to identify the most common causes of accidents at work (Figure 1) and select solutions formulated in the LM concept that allow for the reduction of their occurrence (Table 1). The analyses focused on the significant causes of accidents where the use of Lean Manufacturing tools improves work safety.

Incorrect employee behavior was the most common cause of accidents at work in the steel sector in Poland in 2009-2019 – accounting for 46,8 % of all the causes of recorded events (Figure 1). The occurring accidental events were caused, among others, by the ignorance of the hazards and OSH regulations, disregard of workplace hazards, surprise by an unexpected event, and lack of experience or concentration. In view of the above, it seems necessary to implement some solutions aimed at reducing or eliminating the occurrence of the causes under analysis. Such solutions may surely include (Table 1):

OPL – that fill knowledge gaps and provide employees with the information they need to perform production tasks. Moreover, OPLs have a substantial impact on bringing back to the employees' attention the issues of existing hazards and increasing awareness of their occurrence (high impact on reducing accidental events +++). One point lessons are a solution applied within the framework of the following methods: VM, SMED or AM,

SoW – instructions, procedures that employees should get familiar with and strictly follow, both in terms of working methods and OSH (high impact on safety improvement +++),

VM – clear marking of hazardous places and zones, including traffic routes and roads. The use of VM in the scope of keeping employees informed of hazards, other risks related to the existing hazards, as well as applicable orders and bans leads to an improvement of work safety as regards raising employees' awareness (high impact +++),

Kaizen (suggestion system, Quick Kaizen projects) – it is recommended that employees become engaged in shaping safe working conditions and submit their own ideas to reduce hazards, and consequently, their causes (medium impact on the improvement of safety ++).

application of the 5S/6S method, in particular in relations to standardization and employee self-discipline (medium impact ++).

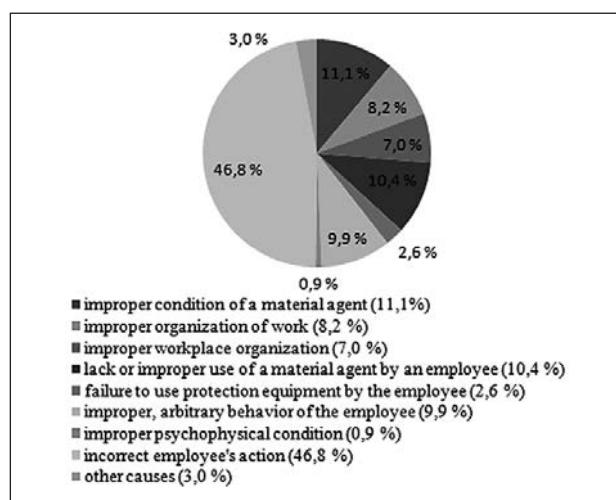


Figure 1 Summary list of the repeatability of the causes of accidents at work in 2009-2019 [8]

Other prevailing causes of accidents in the steel sector in Poland were: improper condition of the material factor (accounting for 11,1 % of all the causes) and lack of or improper use of that factor (10,4 % of all the causes) – Figure 1. The scope of the first cause covers: any design defects or improper technical and ergonomic solutions of the material factor. The second cause includes, among others, the use of a material factor that is not appropriate for a given task, use of a material factor contrary to its intended purpose, improper holding, fastening, and securing of the material factor. It is possible to reduce the occurrence of the causes of accidents of that type using (Table 1):

OPL – drawing attention to the necessity to control the material factor, security devices, applied protective measures has a high impact on the reduction of the cause due to the constant supervision of its occurrence, VM – marking of control elements, use of light or sound signaling, lockout-tagout system to prevent hazards,

standardization of work – placement in a visible place and compliance with visual standards, safety instructions in the workplace.

These solutions have a high impact (+++) on the improvement of work safety, in particular in the case where employees perform activities under Autonomous Maintenance or during changeovers (SMED). The use of SMED and Autonomous Maintenance has a high impact (+++) on the work safety situation – actions involving lubrication, cleaning, adjustment or the proper use of tools and other material factors should be standardized, and it is essential that safety of the participants in the process be ensured. The application of the 5S/6S method as regards systematics and work standardization will also produce an impact on the reduction of that cause (medium impact ++) – Table 1.

With respect to the reduction of the improper and unauthorized employee behavior (9,9 % of all the causes of accidents) – Figure 1, it is proposed that the same tools of the same impact as in the case of incorrect employee behavior are applied. That category relates to, among others, performing work not included in the job description, passing

Table 1 Identification of the causes of accidents and LM tools in terms of improving work safety [own research]

Causes of accidents at work	Lean Manufacturing tools						
	OPL	5S/6S	VM	AM	SMED	SoW	Kaizen
1	2	3	4	5	6	7	8
Incorrect employee's action	+++	++	+++			+++	++
Improper condition of a material agent	+++		+++	+++	+++	+++	
Lack or improper use of a material agent by an employee	+++	++	+++	+++	+++	+++	
Improper, arbitrary behavior of the employee	+++	++	+++			+++	++
Improper organization of work	+++	+++	+++			+++	++
Improper workplace organization	+++	+++	+++			+++	++
Failure to use protection equipment by the employee	+++		+++				++

over, walking or staying in prohibited places, or performing professional activities without removing the hazard.

Improper work organization accounted for 8,2 % of all the causes of accidents (Figure 1). It relates to, among others, improper division of work and planning of tasks, performance of work not included in the job description, lack of instructions, lack of supervision, tolerance of deviations from the applicable regulations and OSH principles by supervisors, performance of work without undergoing training. It is recommended that the following solutions aimed at mitigating this cause be adopted (Table 1):

SoW – development of instructions, standards as defined in the Training Within Industry program in terms of = work methods, employee instruction and OSH (high impact on safety improvement +++), regular short trainings on safety during the performance of work (OPL) – (high impact on safety improvement +++), use of pictograms and other visual markings to prevent accidents at work (VM) – (high impact on safety improvement +++), application of the principles of the 5S/6S method that discipline employees and their supervisors (high impact on safety improvement +++), suggestion system (kaizen) in which employees may submit suggestions on possible improvements in the context of their work (medium impact on safety improvement ++).

The same solutions are proposed for the cause related to the improper organization of the workplace (7,0 % of all the causes of accidents) that includes, among others, improper arrangement of devices, raw materials and semi-finished products at the work station, lack of passage and access to the workplace, presence of unnecessary objects, substances or energy, or lack of personal protective equipment. In this context, the 5S/6S method is of the greatest significance (as a means of securing an orderly and safe workplace). An important concern in terms of occupational safety and health is the failure to apply protective measures by employees. This cause accounted for 2,6 % all of the causes and it is therefore recommended that employees are reminded during every shift of the necessity to use protection (OPL) and that the places where the use of personal protection is mandatory are marked (VM) – high impact on safety protection and reduction of the causes of accidents (+++). It also seems important to involve employ-

ees in submitting ideas and suggestions on the adopted preventive measures. The Kaizen suggestion system may therefore be applied (medium impact on the reduction of the causes of accidents ++).

CONCLUSIONS

An analysis of the data compiled in Table 1 led to the conclusion that one point lessons, visual management and standardization of work have a high impact on the reduction of the causes of accidents in the metallurgical sector in Poland. Apart from their high impact, each of these tools affected the possibility of reducing all the investigated causes of accidents in the steel sector in Poland.

The use of the tools of the LM concept contributes to the improvement of work safety and each applied tool impacts the reduction of the causes of accidents at work to a different extent. An effective solution would therefore require the implementation of several tools simultaneously in the context of reducing the causes of accidents at work in the steel sector.

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