

Implementation of Kaizen tools in managing production processes at a steelworks

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Abstract

Research background: Heavy industry plants are increasingly turning to Kaizen tools – previously known mainly from the automotive industry – in an effort to reduce downtime costs and waste in production processes. However, the literature primarily describes the general principles of this philosophy, and far less frequently focuses on its specific implementations in mass production environments, such as a ribbed bar rolling mill.

Purpose: The aim of this article is to conduct a qualitative assessment of the role of selected Kaizen tools in improving the operational efficiency and work organisation of the ribbed bar rolling mill department, and to formulate recommendations for further improvements.

Methodology: A qualitative case study was employed, comprising participant observation, analysis of technical and operational documentation, and analysis of breakdowns and changeovers. The study was carried out by two authors: a practitioner employed at the company under study, who was actively involved in improvement processes, and an external researcher who reviewed the data and their interpretation in order to minimise bias in the assessment.

Findings: The implementation of a cascading communication system, 5S standards, a systematic root-cause analysis of breakdowns and standardised changeover procedures enabled a shift from a reactive to a preventive model, as well as the standardisation of changeover time (25 operations, approximately 2 hours 30 minutes). The elimination of recurring breakdowns and the reduction in the time taken to rectify them should, in the long term, also help to reduce the variability of the Overall Equipment Effectiveness (OEE) metric, although data to measure this were not available within the scope of this study.

Practical implications: The standards developed (checklists, Service Call Reporting & Analysis sheets, Gantt charts) can be transferred to other production lines and profiles and serve as a starting point for the development of a comprehensive Total Productive Maintenance system.

Originality / value: The article presents an integrated implementation of a Kaizen toolkit in the steel industry, based on the direct professional experience of one of the authors. The combination of a theoretical perspective with the engineering practice of a specific production department is rarely encountered in the literature on the subject.

Keywords: Kaizen; Lean Management; 5S; SMED; OEE.

JEL classification: L23; M11.

1. Introduction

In heavy industry, increases in production efficiency are less and less often the result of investment in machinery alone, and depend to a greater extent on the organisation of work and the level of waste occurring in production processes. One of the most commonly used approaches to

reducing waste is the Kaizen philosophy, defined as a method of continuous improvement based on small, systematic enhancements (Imai, 2007; Walentynowicz, 2024). However, the literature is dominated by descriptions of its application in the automotive industry and discrete manufacturing, whilst analyses concerning continuous processes in the steel industry – where automation, shift work and the scale of operations create specific implementation conditions – are much less common (Walentynowicz, 2024; Piasecka-Głuszak, 2011).

As the literature review presented in the following section of this article shows, existing studies usually focus on individual tools or on the stated benefits of the Kaizen philosophy, whilst less frequently presenting a comprehensive, documented process of diagnosis and implementation in a flow production environment. Consequently, a research gap can be identified regarding the lack of detailed implementation descriptions linking theoretical tools to the operational practice of a specific production department.

The aim of this article is to conduct a qualitative assessment of the role of selected Kaizen tools in improving the operational efficiency and work organisation of the ribbed bar rolling mill department, and to formulate recommendations for further improvements. In light of this aim, the following research questions have been formulated:

- Q1: Which characteristics of production processes and which KPIs (Key Performance Indicators) can be used to describe changes in the department's productivity before and after the implementation of Kaizen tools?
- Q2: How do organisational culture and employee engagement influence the effectiveness of Kaizen tool implementation?
- Q3: What barriers and critical factors hinder the implementation of Kaizen in a manufacturing company?
- Q4: How did the implementation of selected Kaizen tools translate into the observed changes in operational efficiency and quality?

This article takes the form of a case study based on the direct professional involvement of one of the two authors (hereafter the practitioner-author), who is an employee of the department under analysis, and on his active participation in the optimisation processes described. The second author (hereafter the academic author), who is not employed by the company and did not take part in the implementation, was responsible for the theoretical framework and the research design, and acted as an external reviewer of the empirical material and its interpretation. The text is organised as follows: following a review of the literature, the research methodology is presented; the subsequent sections present the results of the pre-implementation assessment and a description of the implementation of Kaizen tools, together with an evaluation of the outcomes achieved; the final section sets out conclusions and recommendations for the further development of the system towards a full Total Productive Maintenance (TPM) model.

2. Literature review

The concept of Kaizen stems from the American idea of continuous improvement, which was developed in Japan after the Second World War and popularised by M. Imai as a management philosophy aimed at systematically improving quality and efficiency in all areas of a company's operations (Imai, 2007; Krząstek & Niemczyk, 2022). The conceptual basis for Kaizen is the Toyota Production System, from which the idea of Lean Management evolved, focused on eliminating everything that does not add value for the end customer (Womack et al., 2007). In the literature,

Kaizen is defined as a bottom-up process of continuous improvement implemented through small steps, as an organisational management system integrating safety, quality, timeliness and cost (SQDC) indicators, or as a set of targeted, time-limited implementation projects (Walentynowicz, 2024). The most important element of the concept, however, is its focus on eliminating three categories of waste: *muda* (waste), *muri* (overburden) and *mura* (process instability) (Radin Umar et al., 2023). The operational basis of Kaizen is the Plan–Do–Check–Act (PDCA) cycle, which enables the systematic identification of problems, the testing of solutions and the standardisation of effective corrective actions (Nguyen et al., 2023). Among the tools supporting continuous improvement at the workstation level, the 5S methodology (Seiri, Seiton, Seiso, Seiketsu, Shitsuke) plays an important role; its consistent implementation leads to the elimination of time wasted searching for tools and materials, as well as to improved workplace safety (Niemczuk, 2017). In the field of maintenance, an important complement is the TPM (Total Productive Maintenance) concept, which focuses on achieving the so-called ‘three zeros’ (zero accidents, zero shortages, zero breakdowns) by involving staff at all levels in the preventive maintenance of machinery (Slavina & Štefanić, 2024). An analytical tool supporting TPM is Root Cause Analysis, based, amongst other things, on the 5x Why technique, which enables the distinction between apparent causes and the actual source of a failure (Pietsch et al., 2024).

A separate group of tools comprises methods for reducing changeover times, including the Single Minute Exchange of Die (SMED), the essence of which is the division of changeover activities into internal tasks – i.e. those that can only be carried out whilst the machine is stopped – and external tasks, which can be performed before or after the machine is stopped (Stolarska-Szeląg, 2023). The literature emphasises that the application of SMED principles leads to a significant simplification and standardisation of the process (Braglia et al., 2023).

In the literature, the effectiveness of implementing Kaizen technical tools is unequivocally linked to cultural factors. Walentynowicz (2024) points out that a prerequisite for the sustainability of change is a participatory management style based on the presence of management at the point where value is created (*gemba*, *genbutsu*) and on fostering a sense of shared responsibility amongst staff for the outcomes of the process. Among the determinants of success for a culture of continuous improvement are also the active involvement of top management, the workforce’s identification with the organisation’s objectives, cooperation and teamwork across functional boundaries, transparency and open communication, and an incentive system linked to the actual outcomes of improvement activities (Walentynowicz, 2024). Piasecka-Głuszak (2011) draws similar conclusions. Based on a survey of 29 Polish companies, she identifies the main barriers to implementing the Kaizen Management System as employee resistance to change, a lack of genuine commitment from senior management, a shortage of time for improvement activities, and communication barriers between departments. Midor and Lenart (2015) supplement this picture with critical success factors, such as conducting information and education campaigns, formalising the process for reporting improvements (regulations, Kaizen cards), establishing an incentive scheme, utilising IT infrastructure to manage reports, and carrying out a pilot phase in accordance with the PDCA cycle prior to full implementation across the entire department.

Apart from the cultural factor, measuring process efficiency is an integral part of a continuous improvement system. In industrial practice, the key metric remains the Overall Equipment Effectiveness (OEE) indicator, which is the product of availability, productivity and quality. This indicator was developed by S. Nakajima as part of the TPM concept (Wirkus & Kukułka, 2015). Milewski (2021) emphasises that traditional accounting systems, based on aggregated data, do not allow for the

precise identification of sources of waste, which in many organisations can account for between 40 and 50 per cent of process duration; remedies here include, amongst others, Value Stream Mapping (VSM) and Visual Management supported by the 3G technique (Gemba, Genbutsu, Genjitsu).

In the classical sense, the efficiency of a production process is defined as the ratio of the results achieved to the inputs incurred, distinguishing between technical efficiency (the ratio of production volume to the maximum output achievable from given resources) and allocative efficiency (the degree to which inputs are utilised in optimal proportions) (Milewski, 2021). In industrial practice, OEE performance is typically benchmarked against so-called 'world-class' reference values, although companies may set their own targets tailored to their specific technological context (Wirkus & Kukułka, 2015).

Research specifically focused on the metallurgical sector remains relatively scarce, although it confirms both the potential and the specific conditions for implementing Lean in this environment. Abdulmalek and Rajgopal (2007) note that Lean is applied much more frequently in discrete manufacturing than in the process sector, due to perceived barriers that make managers reluctant to adopt it. Using the example of a large integrated steelworks, they demonstrated that value stream mapping, supported by 'before' and 'after' simulations, can reveal potential reductions in production lead times and a decrease in work-in-progress stocks. Todorut et al. (2016) emphasise that, as metallurgical companies have limited influence over raw material prices, operational efficiency is the source of their competitiveness. The authors propose a phased approach to Lean management, starting with quick wins, moving through optimisation, and culminating in sustainability, in which the 5S method, visual management, Kaizen, TPM and SMED are applied in conjunction, with the involvement of staff at all levels. Research carried out in rolling mills and tube manufacturing plants points in the same direction. Sharma et al. (2021) reported an increase in productivity of around 30 per cent and a reduction in the number of defective products of around 70 per cent following the implementation of the Kaizen method in a rolling mill, whilst Ahuja and Kumar (2009) demonstrated that strategic TPM initiatives in precision tube manufacturing plants contributed significantly to improved production performance. However, these studies focus mainly on performance indicators and describe the implementation process itself only in general terms. As can be seen, the theoretical body of work on individual Kaizen tools is extensive, and sector-specific studies confirm their relevance to metallurgy; however, there is a lack of studies demonstrating their integrated, documented implementation in the context of continuous, large-scale steel production. This article fills that gap by presenting a case study of the implementation of the Daily Kaizen system, 5S standards, Service Call Reporting & Analysis (SCRA) analysis and the SMED methodology at the Ribbed Bar Rolling Mill Department.

3. Methods

The article employs a qualitative research approach in the form of a case study, justified by the exploratory nature of the research problem and the need for an in-depth understanding of the implementation process within its natural organisational context. The study was conducted at the Ribbed Bar Rolling Mill Department of a company in the steel industry, specialising in the thermomechanical processing of steel.

The empirical research relied on the direct professional involvement of the practitioner-author who, as an employee of the department under study, played an active role in the optimisation processes described, including the development of 5S standards and the SMED methodology, the

improvement of systematic failure analysis using the SCRA method, and the co-creation and supervision of the implementation of the Daily Kaizen system. The empirical data were collected using three complementary research techniques over a period of several months of observation whilst employed:

- participant observation (Gemba Walk) – direct verification of process flows at the actual point of execution;
- analysis of the department's technical and operational documentation, including SCRA sheets, 5S cards, changeover schedules and KPI reports;
- case studies of specific incidents – breakdowns and changeovers on the production line – illustrating how the implemented tools operate.

The scope of the study covered an assessment of the pre-implementation status and the subsequent phases of implementation: the preparatory phase (development of templates and training), the visual implementation phase (installation of communication boards, 5S standards), the stabilisation phase (rigorous fault analysis, testing of reconfiguration paths) and the verification and standardisation phase.

The assessment of the effectiveness of the implemented tools drew on the set of KPIs used within the department (including OEE, yield and a detailed breakdown of production and maintenance downtime, as defined in Table 2) as contextual information, but was based primarily on a qualitative assessment of changes to communication and organisational processes, carried out using a before-and-after method. Due to the exploratory and implementation-oriented nature of the study, no statistical analysis of the significance of changes in the indicators was carried out in this article. The results obtained are descriptive and diagnostic in nature, typical of action research conducted from the perspective of a practitioner-researcher.

The collected data were subjected to qualitative analysis by comparing the situation before and after implementation in each of the four identified areas (operational communication, workstation organisation, fault analysis and changeovers), as well as by linking recurring patterns identified in each area to the research questions formulated for the study. The root cause chains for individual incidents were reconstructed using the '5 Whys' technique applied to the relevant SCRA documentation.

The analysis was carried out in four steps. First, the source material (SCRA sheets, 5S cards, changeover schedules, KPI reports and notes from participant observation) was catalogued and assigned to one of the four areas of analysis. Second, for each area, the pre-implementation state was described on the basis of the documentation and observations from the diagnostic phase and compared with the state at the end of the verification and standardisation phase. Third, the recurring patterns identified within the individual areas were compared across areas and linked to the research questions (Q1–Q4). Fourth, the resulting interpretations were checked by the academic author against the source documentation, as described below. The effectiveness of the implementation was assessed against criteria derived from the operational objectives set for each area (Section 4.2): for Daily Kaizen – the existence of a regular, structured shift handover with a fixed agenda and duration, and of a defined escalation path for anomalies; for 5S – the presence of visual standards and dedicated storage locations in critical areas, and the time needed to locate spare parts during breakdowns; for TPM/SCRA – the share of breakdowns lasting over 30 minutes that were subjected to root cause analysis, the timeliness of SCRA analyses and the recurrence of failures of the same type; for SMED – the existence of a documented changeover sequence with assigned roles and the repeatability of changeover time irrespective of the shift crew. Implementation in a given area was regarded as effective when these criteria were met in the

verification and standardisation phase and the solutions developed were formally adopted as binding operational standards. The KPIs listed in Table 2 served as contextual information rather than as a basis for quantitative inference.

The dual role of the practitioner-author creates a risk of bias in the assessment. Several measures were adopted to mitigate this risk. First, data triangulation was employed. Conclusions were drawn only in cases where participant observation was corroborated by documentation compiled independently of the practitioner-author. Second, the roles of the authors were separated. The academic author, who was not involved in the implementation, independently reviewed the source documentation and the before-and-after comparisons. Third, the results distinguished between findings supported by documentation and those based solely on the observations of the practitioner-author, with the latter being presented as preliminary. Fourth, in addition to the effects of implementation, the obstacles and difficulties encountered were also described. These measures limit, but do not eliminate, the risk of bias, which was recognised as one of the study's limitations.

4. Results and discussion

4.1. The production process and the performance indicator system

The company under review operates in the steel industry and specialises in the thermomechanical steel processing. The subject of the implementation analysis is the Ribbed Bar Rolling Mill Department, where the production process is of a continuous nature: the charge, heated in a heating furnace, is directed onto two parallel production lines (Lines A and B), consisting of alternately arranged vertical and horizontal rolling mills (Fig. 1). This configuration requires rigorous balancing of both lines, as the formation of a bottleneck on either one immediately limits the throughput of the entire system.

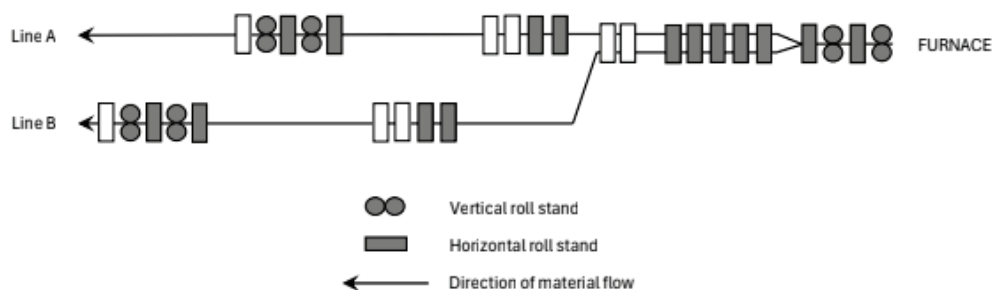


Figure 1. Material flow diagram for the rolling mills (Line A and Line B)

Source: authors' own elaboration.

Production comprises a diverse range of ribbed bars, both straight (BS) and coiled (C), with standardised nominal weights per linear metre (Table 1) which serve as a benchmark for assessing the process's compliance with the technical standard.

Monitoring of the department's efficiency was based on a comprehensive set of KPIs (Table 2), including, amongst others, material yield, tonnage output in relation to time spent and effective time, the number of jams, the BBC ratio (the number of billets discharged from the furnace between two consecutive jams), unit consumption of energy resources, and a detailed breakdown of downtime (product changeover TK/TR, production downtime TS/TO/TZ/TI, maintenance downtime UM/UE). A composite metric combining these dimensions is the OEE, calculated as the product of availability, performance and quality (Wirkus & Kukułka, 2015).

Table 1. List of product ranges and nominal weight per running metre for rolled sections

Production profile	Nominal mass [kg/m]
BS 8 x 3	0.395
BS 10 x 3	0.617
BS 12 x 3	0.888
BS 14	1.21
BS 16	1.58
BS 20	2.47
BS 25	3.85
BS 28	4.85
BS 32	6.31
C 10	0.617
C 12	0.888
C 14	1.21
C 16	1.58
C 20	2.47

Source: authors' own elaboration.

Table 2. KPIs monitored at the Ribbed Bar Rolling Mill Department

KPI	Unit
Yield	%
Output relative to time spent	Mg/h
Output relative to effective time	Mg/h
Number of jams	units
BBC (number of billets between jams)	units
Energy	kWh/Mg
Gas	kWh/Mg
Total production stoppages	%
Product changeover (TK + TR)	%
TK – profile change	%
TR – dimensional adjustment	%
Production stoppages	%
TS – replacement of rolls, stands and passages	%
TO – adjustment of fittings	%
TZ – downtime for jams	%
TI – other	%
Maintenance downtime	%
UM – mechanical and power-related	%
UE – electrical and automation-related	%
Utilisation (time utilisation)	%
OEE	%

Source: authors' own elaboration.

Such a comprehensive KPI system enables the precise identification of sources of waste; however, as the assessment showed, simply measuring these indicators does not guarantee an improvement in efficiency without corresponding changes in the organisation of work and communication.

4.2. Implementation plan

Based on the findings of the pre-implementation assessment (described in Section 4.3), a structured implementation plan was drawn up, covering the definition of operational objectives, a phased timetable and the allocation of responsibilities within the project team. Objectives were formulated separately for each of the four identified areas: for Daily Kaizen, the establishment of a permanent channel for

horizontal and vertical communication enabling a rapid response to anomalies; in the area of 5S, the improvement of ergonomics and workplace safety through the visualisation of critical parameters and the organisation of spare parts management; in the area of TPM/SCRA, the increase of the technical availability of machinery by eliminating chronic breakdowns through a thorough root cause analysis; in the area of SMED, the reduction and standardisation of changeover times.

Given the need to maintain continuity of operations at the rolling mill, the implementation was divided into four phases: the preparatory phase (development of new templates, including SCRA sheets and cleanliness cards, and initial training for foremen), the visual implementation phase (installation of noticeboards and the physical implementation of 5S standards in critical areas, such as hydraulic rooms and workshop racking), the process stabilisation phase (introducing a rigorous system for analysing breakdowns lasting over 30 minutes and testing the new reconfiguration paths during planned product range changes) and the verification and standardisation phase (analysis of the results obtained, amendments to instructions and formal approval of the solutions as binding operational standards).

Implementing the plan required the involvement of staff with a range of skills and a clear division of roles: senior management carried out regular visits to the production floor (Gemba Walk) to monitor progress and provide direct support to the team; shift leaders (maintenance and production foremen) were responsible for overseeing the implementation of new procedures and coordinating the reorganisation processes; a working group (mechanics, operators) took part in 5S workshops and provided technical feedback on the standards being developed; technical support provided the materials necessary for visualising the standards (boards, signage, workshop tools).

4.3. Pre-implementation assessment

The baseline assessment was carried out using participant observation (Gemba) and document analysis, focusing on four areas that directly impact the efficiency of the production flow.

In the area of operational communication (Daily Kaizen), a high degree of centralisation in the flow of information was identified: meetings were held amongst senior management, without structured, short briefings at the workstation level. The absence of a 'bottom-up' communication model meant that maintenance staff only became aware of minor faults once a full breakdown had occurred, which prevented preventive action and resulted in a waste of frontline staff's intellectual potential.

In the area of workstation organisation (5S), the presence of unnecessary items and scrap material was identified in work areas and passageways, a lack of visual markings indicating operating ranges on technical gauges (pressure gauges, level indicators), as well as a lack of dedicated storage areas for spare hydraulic hoses and spare parts, which, in emergency situations, prolonged the time taken to locate a suitable replacement and, consequently, increased downtime.

In the area of fault analysis (TPM/SCRA), the existing reporting system was formal and bureaucratic: documentation focused on a chronological description of the incident and ad hoc remedial measures, without a defined threshold for analytical intervention or cross-functional cooperation (production–maintenance), which resulted in the recurrence of the same failures.

In the area of changeovers (SMED), the existing changeover procedures were too general in nature, lacking a detailed 'step-by-step' sequence of actions, without a clear division of roles between the production and maintenance teams, and without utilising the potential of tasks that could be carried out before the line was stopped (external activities as defined by SMED), which led to significant variation in changeover times depending on the shift crew.

The identified shortcomings indicated that the main source of losses was not the lack of technological sophistication of the production line, but rather insufficient standardisation and a lack of visual management tools, which directly determined the scope of the solutions implemented.

4.4. Implementation of Kaizen tools

The Shift Team Board was introduced as a hub for coordinating corrective and preventive actions, alongside a standardised handover agenda that completed the communication process within a shift in 8 minutes (including 90 seconds for safety matters, 3 minutes for analysing indicators, and 2 minutes for task allocation). Separate monitoring forms were introduced on the board for mechanical and hydraulic (URM) and electrical and automatic (URE) downtime, a timeliness indicator for SCRA analyses and a preventive maintenance completion rate, whilst ongoing tasks were categorised as ‘in progress – escalation – completed’ and assigned to specific specialisms (mechanic, hydraulics technician, automation technician, electrician, power engineer).

During the Seiton step, the stockrooms and workshop shelving were reorganised to provide a dedicated space for each component, and a wall-mounted organisation panel was introduced for spare hydraulic hoses, with a description of the technical purpose of each hose. In the Seiso step, shadow boards for cleaning tools and standardised containers for clean and used absorbent material were introduced. In the Seiketsu step, a visualisation system for working fluid levels (green/red zones on oil tank gauges) was implemented as an error-proofing measure, reducing the risk of operators misjudging the condition of the equipment.

A standard was adopted whereby any breakdown lasting longer than 30 minutes is subject to a mandatory, team-based root cause analysis using a standardised SCRA worksheet, which records, amongst other things, the service response time (required to calculate the Mean Time to Repair (MTTR)) and the categorisation of causes (design fault, natural wear and tear, operational error, lack of standard). This mechanism is illustrated by the example of a jam in the cutting shear area, which caused a 53-minute line stoppage. The 5-Why analysis led from the symptom (strip jamming in the looping machine’s outlet hopper) through successive intermediate causes (a bent end of the strip getting caught, an undercut section of material, incorrect setting of the diverter and wear of the cutting edges) to the root cause: an incorrect assessment of the equipment’s technical condition and setting parameters prior to the start of rolling. The direct outcome of the analysis was the development of a checklist for the shearing area, integrating the tasks of automation engineers, mechanics and operational staff as a standard for verifying the line’s operational readiness.

A proprietary ‘reconfiguration paths’ system was developed, the core of which is a detailed schedule (Gantt chart) defining the sequence of 25 technical operations for a given type of reconfiguration (e.g. from the C14 line to the BS12x3 line), with a total standardised duration of 2 hours and 30 minutes (Fig. 2). The schedule assigns tasks to 12 specialised work teams (production, maintenance, crane operation), specifying the start time of each operation relative to the start of the changeover, which allows parts of the work to be carried out in parallel and eliminates downtime resulting from waiting for available resources. The schedule is supplemented by a checklist of preparatory activities and materials, which classifies as many tasks as possible (including positioning of cages, preparation of tools, checking oil levels) as external activities within the SMED framework, carried out whilst production is still in progress.

Roll-change schedule

Date:

Time step	Total time
0:00:45	2:30:00

No.	Operation	Estimated time (s)	Start	End	Start after	Team no.	Start (chart)	Duration (chart)
1	Change of stands 12 and 13 to pass-through tables	1608	0:00:00	0:26:48	0	P1	0:00:00	0:26:48
2	Change of stands 14, 15 and 16. Change of stand 17 to pass-through table	1608	0:00:00	0:26:48	0	P2	0:00:00	0:26:48
3	Change of stands 18, 19 and 20. Change of stand 21 to pass-through table	1608	0:26:48	0:53:36	2	P2	0:26:48	0:26:48
4	Change of stands 22, 23, 24 and 25. Insert stand 26	2200	0:00:00	0:36:40	0	P3	0:00:00	0:36:40
5	Change of stands 27, 28, 29 and 30. Insert stand 31	2220	0:36:40	1:13:40	4	P3	0:36:40	0:37:00
6	Removal of guide spine behind stand 30	720	0:00:00	0:12:00	0	UR1	0:00:00	0:12:00
7	Installation of trough and roller conveyors behind cooling box TC LA	2200	0:12:00	0:48:40	6	UR1	0:12:00	0:36:40
8	Removal of troughs and roller conveyors behind stand 25	1290	0:48:40	1:10:10	7	UR1	0:48:40	0:21:30
9	Change of loopers L10 and installation of looper L11	1200	1:10:10	1:30:10	8	UR1	1:10:10	0:20:00
10	Change of looper L14 and installation of looper L15	1200	1:30:10	1:50:10	9	UR1	1:30:10	0:20:00
11	Installation of trough behind cooling box TC LB	1400	1:50:10	2:13:30	10	UR1	1:50:10	0:23:20
12	Moving of cooling box TC A3	926	0:00:00	0:15:26	0	UR2	0:00:00	0:15:26
13	Moving of cooling box TC B3	926	0:15:26	0:30:52	12	UR2	0:15:26	0:15:26
14	Insertion of cooling box TC B1	1204	0:30:52	0:50:56	13	UR2	0:30:52	0:20:04
15	Insertion of cooling box TC A1	1204	1:10:10	1:30:14	8	UR2	1:10:10	0:20:04

Roll-change schedule (Gantt)

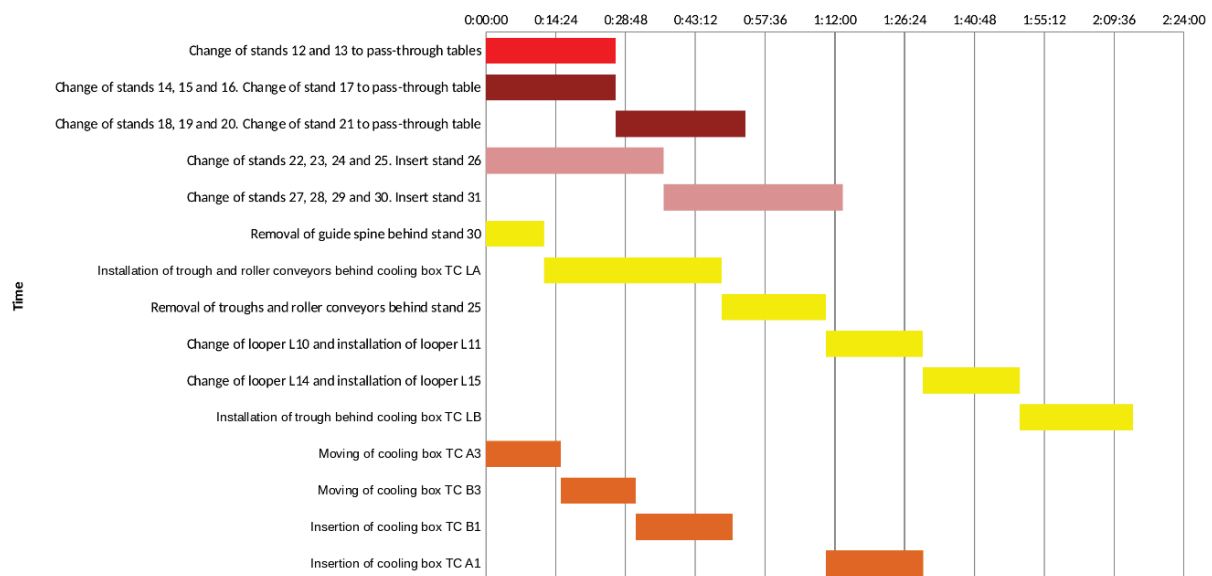


Figure 2. Operational schedule for the conversion of the line from C14 to BS12x3 (Gantt chart)

Source: authors' own elaboration.

4.5. Assessment of the effectiveness of implementation

The effects of the implementation are primarily qualitative in nature and relate to the stabilisation of processes that were previously subject to high variability. The shift team's noticeboard has standardised the source of information on the technical condition of the department ('single source of truth'), eliminating the need to seek data from supervisors and reducing response times to ongoing issues. The implementation of 5S, including the labelling of workshop shelving, has, according to the practitioner-author's observations (not verified by time measurements), reduced the time taken to

retrieve a valve during a night-time breakdown by a dozen or so minutes, which has a direct impact on the MTTR metric. The SCRA system has changed the criterion for assessing the effectiveness of preventive measures – from ‘no breakdowns’ (unrealistic in a steelworks context) to the absence of recurring breakdowns of the same type, as confirmed by the case study of the shearing machine. The standardisation of changeovers under SMED has enabled a consistent changeover time to be achieved (2 hours 30 minutes for 25 operations) regardless of the shift composition, eliminating so-called time variation and enabling production planners to precisely determine the moment to resume material dispatch from the furnace.

With regard to the research questions formulated, the results obtained indicate that: (Q1) OEE remains the most useful diagnostic indicator, supplemented by a detailed breakdown of downtime (TK/TR/TS/TO/TZ/TI, UM/UE), which allows the specific source of losses to be pinpointed, rather than merely confirming their occurrence; (Q2) an organisational culture based on a rigid hierarchy constituted an initial barrier, which was overcome by involving operators in the design of standards (reconfiguration paths, checklists) and through regular Gemba Walk visits by management, which fostered a sense of shared responsibility; (Q3) the main barrier was resistance to changing habits and an initial lack of cooperation between production and maintenance, which was overcome by formalising procedures and visualising the benefits; (Q4) the tools implemented can be expected to have a complementary effect on OEE – SMED improves the availability component by shortening and standardising changeovers, whilst 5S and SCRA reduce the number and duration of breakdowns, which should also translate into higher material yield by reducing the number of jams.

The results obtained are consistent with the literature emphasising the primacy of organisational and cultural factors over the purely technical dimension of Kaizen (Walentynowicz, 2024; Piasecka-Głuszak, 2011) and confirm the role of visual management and the 3G technique as mechanisms supporting the monitoring of effectiveness (Milewski, 2021). The added value of this article compared with previous studies lies in its integrated presentation – documented at the level of specific tools (spreadsheets, schedules, checklists) – of the implementation under the specific conditions of flow production in the steel industry, which are less frequently described in the literature than cases from the automotive industry.

At the same time, the limitations of the study should be noted. The assessment of effectiveness is qualitative in nature and is based on observations of a single department within a single company, without a complete, standardised series of OEE measurements taken before and after implementation; this limits the possibility of generalising the results and does not allow for the statistical verification of the significance of the observed changes. Moreover, as the practitioner-author co-designed and supervised the solutions being evaluated, a residual risk of evaluative bias cannot be ruled out despite the safeguards described in Section 3; effects identified solely on the basis of his observations therefore require confirmation through independent measurement.

The article does not present a comparison of OEE figures before and after implementation, as this metric was not recorded in a complete and methodologically consistent manner throughout the entire period preceding and following implementation. Comparing incomplete data series would carry the risk of attributing changes resulting from other factors – such as the product range or the schedule of planned downtime – to the Kaizen tools. The quantitative data presented therefore describe the standards introduced and individual events, rather than the overall scale of the effects. It should also be emphasised that the aim of a single case study is analytical rather than statistical generalisation. The results are intended to illustrate the mechanisms through which Kaizen tools operate in continuous steel production, rather than to estimate the scale of their effects on the population of steelworks.

5. Conclusion

The case study confirms that a sustainable improvement in operational efficiency within the heavy industry sector requires simultaneous action on two fronts: the technical front (specific Kaizen tools) and the organisational and cultural front (the involvement of employees and management). The implementation of a cascading communication system, 5S standards, systematic root cause analysis of failures (SCRA) and standardised changeover procedures (SMED) at the Ribbed Bar Rolling Mill Department enabled a transition from a reactive model, based on ad hoc rectification of the consequences of breakdowns, to a standardised and preventive model, in which key processes have become predictable and repeatable.

The most important theoretical conclusion drawn from the study is the confirmation that, without clearly defined standards and without the involvement of front-line staff – regarded as experts in their own workstations – in the process of developing them, Kaizen technical tools remain imposed solutions rather than accepted operational practice. From a managerial perspective, the active, physical presence of management at the point of value creation (Gemba Walk) plays a key role, as it builds trust and shifts the focus of technical supervision from a purely controlling function to a supportive one.

For business practice, the standards developed during implementation – the SCRA worksheet, control checklists, Gantt charts for changeovers and team board templates – are transferable and can be adapted to other production lines and product ranges within the department under study, as well as to other plants with similar characteristics of flow production. It is recommended that the system's development be continued in four areas: the digitisation of reporting (Digital Lean, including the automatic calculation of MTTR), expanding Autonomous Maintenance by delegating simple maintenance tasks to production operators, developing analogous reconfiguration paths for the remaining rolling mill line configurations, and implementing a system of cyclical 5S audits based on mutual shift-to-shift checks.

The lessons learnt from this implementation confirm that the success of optimisation in heavy industry depends on moving away from a purely theoretical, declarative approach to Kaizen in favour of building a culture of genuine engagement.

Recognising operators as experts in their own roles has enabled the development of standards that are actually adhered to, as they stem from the staff's practical experience rather than from a top-down procedure. The regular, direct presence of management on the production floor proved to be critical to the sustainability of these changes, enabling the rapid removal of technical barriers and the building of mutual trust between the production and maintenance departments – an essential prerequisite for any effective operational transformation.

Areas for further research should include a quantitative, long-term analysis of the OEE indicator and its components before and after implementation, as well as comparative studies involving more than one department or company, preferably conducted by researchers not involved in the implementation. This would allow for the verification of the generalisability of the presented conclusions and an in-depth analysis of the relationship between the maturity of organisational culture and the pace and sustainability of the effects of Kaizen implementation in heavy industry.

6. References

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