การลดเศษวัสดุโดยใช้ระเบียบวิธี DMAIC: กรณีศึกษาของโรงงานผลิตในประเทศพม่า

SCRAP REDUCTION BY USING DMAIC METHODOLOGY: A CASE STUDY OF A MANUFACTURE IN MYANMAR

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บทคัดย่อ

กรณีศึกษานี้มุ่งเน้นไปที่บริษัท Modern Steel ซึ่งเป็นผู้ผลิตผลิตภัณฑ์เหล็กสำหรับการก่อสร้าง มีสถานที่ตั้งอยู่ในย่างกุ้ง ประเทศพม่า ขอบเขตของการศึกษานี้เน้นไปที่สายการผลิตแป (purlin) เพราะเป็นผลิตภัณฑ์หลักที่มีปริมาณการผลิตสูงสุดในบรรดาผลิตภัณฑ์ทั้งหมด บริษัทเผชิญปัญหาด้านอัตราผลิตการเกิดเศษวัสดุสูงในสายการผลิตแป (purlin) อัตราของเศษวัสดุในปัจจุบันอยู่ที่ 3% ซึ่งเกินกว่าอัตราที่ตั้งเป้าไว้ที่ 1% ปัญหานี้มีผลเสียต่อประสิทธิภาพและประสิทธิผลในการผลิต และนำไปสู่ค่าใช้จ่ายที่ไม่จำเป็นที่เพิ่มขึ้น อัตราเศษวัสดุ 3% เทียบเท่ากับประมาณ 22 ตันของวัตถุดิบในช่วงเก้าเดือน ซึ่งส่งผลให้เกิดการสูญเสียถึง 33 ล้านจ๊าตเมียนมา (MMK)

แนวทางการจัดการแบบ ลีน ซิกส์ซิกมา โดยใช้วิธี DMAIC ช่วยให้องค์กรสามารถระบุปัญหา ข้อมูลที่จำเป็นถูกรวบรวมเป็นระยะเวลาเก้าเดือนจากสถานที่ทำงานจริง หลังจากที่ใช้เครื่องมือทางคุณภาพในการวิเคราะห์ปัญหา สาเหตุหลักที่มีผลต่อการเกิดเศษวัสดุถูกระบุไว้มีดังนี้ ไม่มีการระบุขนาดสำหรับการจัดตำแหน่งของคู่มือผู้ใช้และลูกกลิ้งในคู่มือการปรับเครื่องจักร ไม่มีอุปกรณ์นำทางระหว่างสถานีตัดและสถานีขึ้นรูปแผ่น เครื่องถูกออกแบบให้มีระยะห่าง 1500 มม. ระหว่างสถานีตัดและสถานีขึ้นรูป ความยาวที่จำกัดของชุดวัตถุดิบและไม่มีการสอบเทียบตัวเข้ารหัสหมุนอย่างสม่ำเสมอ

หลังจากนั้น ได้มีการพัฒนาวิธีแก้ปัญหาที่มีประสิทธิภาพผ่านการระดมความคิดร่วมกับผู้มีส่วนได้ส่วนเสียในการผลิต และโดยการนำกลยุทธ์การควบคุมไปใช้เพื่อป้องกันการเกิดเศษวัสดุในอนาคต การศึกษานี้แสดงให้เห็นถึงความสำเร็จที่สำคัญ อัตราของเศษวัสดุลดลงมาที่ 1% ซึ่งได้ตามเป้าที่กำหนดของบริษัท ผลลัพธ์นี้แสดงให้เห็นอย่างชัดเจนว่าวิธีการ DMAIC ไม่เพียงแต่ลดอัตราการเกิดเศษวัสดุ แต่ยังช่วยรักษาและปรับปรุงการเพิ่มผลิตภาพในการดำเนินการผลิตด้วย

คำสำคัญ: ลีน ซิกส์ซิกมา DMAIC การลดเศษวัสดุ การผลิต

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Abstract

This case highlights the study of Modern Steel Company, a manufacturer of steel building products located in Yangon, Myanmar. The scope of this study focuses on the purlin production line since it is the main product as the highest production tonnage among all the products. The company faced an issue with a high scrap rate on its purlin production line. The current scrap rate was 3%, exceeding the target rate of 1%. This problem disrupted manufacturing efficiency and effectiveness and led to increased unnecessary costs. The 3% scrap rate corresponded to approximately 22 tons of raw materials over nine months, resulting in a loss of 33 million Myanmar Kyat (MMK).

The Lean Six Sigma methodology, using the DMAIC approach, helped the organization identify the problem. Data were collected over a nine-month period from the actual workplace. After using quality tools to analyze the problem, the root causes contributing to the scrap were identified as follows: Lack of dimensional specifications for the positioning of guides and rollers in the machine adjustment manual, Absence of a guiding device between the cutting station and the roll forming station, A machine design with a 1500 mm. distance between the cutting station and the roll forming station, Limited length of raw material batches and No regular calibration of the rotary encoder.

After that, effective solutions were developed through a brainstorming session with production stakeholders and by implementing control strategies to prevent future scrap occurrences. The study demonstrated a significant achievement: the scrap rate decreased to 1%, as targeted. This result clearly shows that the DMAIC methodology not only reduced the scrap rate but also sustained the improvements and enhanced operational productivity.

Keywords: Lean six sigma, DMAIC, Scrap reduction, Manufacturing

Introduction

This paper is a case study of Modern Steel Company which is a manufacturer of steel building products. The company was established in 2016 in Myanmar and factory located at Thalia Special Economic Zone (TSEZ), Yangon, Myanmar. The company was backing and support of the region’s largest coated steel and building products manufacturer that has been in the region since 1965, with over 2,300 employees in a network of metal coating & painting lines and manufacturing factories across ASEAN. The company manufactures steel building products that deliver form and function from classic corrugated roofs to the latest cladding designs with 3D model, composite steel floor decking and light gauge steel structural components to total design solutions services for steel building construction. Moreover, products of this company such as steel panels for roof and wall cladding, metal floor decking, light gauge steel structural components and steel framings can be found in homes & resorts, carparks, schools & offices, and factories & warehouses in Myanmar.

The company adds value for project owners, contractors, architects, and consultants in the local construction industry by offering innovative products that help save time and money. It collaborates with customers from the early stages of building design, enabling them to bring products to construction quickly while ensuring cost-effectiveness and optimal use of resources.

The products of company were produced by using the cold roll forming technique. This technique is the continuous bending process of the metal strip through several pairs of rollers designed in sequence, the strip going through as per the direction of the rollers rotating until obtaining the desired cross-sectional shape (Paralikas et al., 2013). The cold roll forming process is a manufacturing process for metal products that enables the production of high-quality outputs, reduces development time, enhances efficiency, and minimizes material usage and costs (Wang et al., 2022)

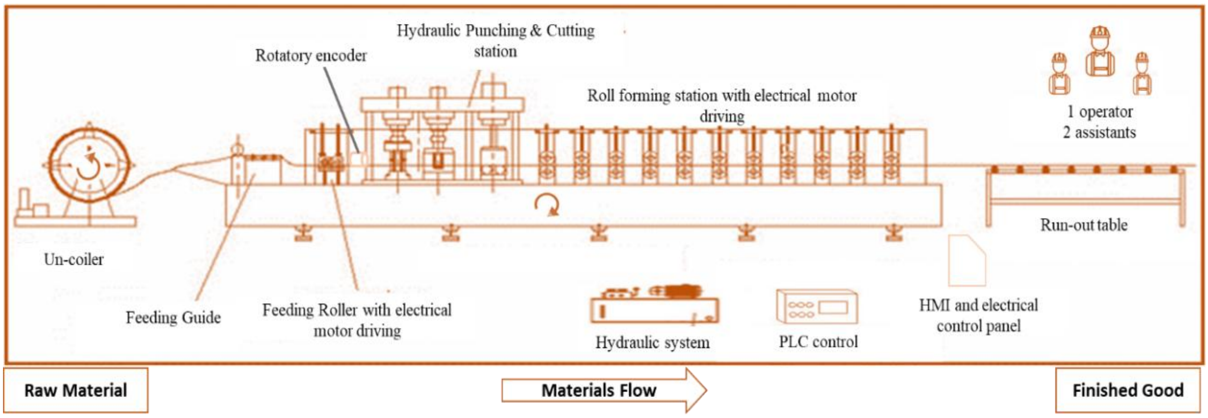
Purlin can be regarded as the main product as the highest production tonnage among all the products. Purlin was produced 687 tons as finished good as well as the highest scrap tonnage (22 tons) compared to other products. Scrap is classified as defective output and is considered a component of the cost of poor quality. The reduction of defects in delivered products has generated substantial benefits for the company (GIRMANOVÁ et al., 2017).

By analyzing historical data for nine months, the author found that the purlin production process caused the highest scrap rate which was 3%, as well as above the control target of Modern Steel Company. It is resulting in a loss of 33 million Myanmar Kyat (MMK).

The company produces two types of purlins, such as C purlin and Z purlin, with various sizes from 100mm to 350mm and thicknesses from 1mm to 3mm, which are produced with a multifunctional automated machine. The production line is operated by one machine operator with the support of two assistants. It consists of major components such as an un-coiler, material feeding guides, material feeding or driving rollers, rotatory encoder, hydraulic punching and cutting station, roll forming station, hydraulic system, PLC (Programming Logic Control) system, HMI (Human Machine Interface) system, and run out table as shown on Figure 1.

Figure 1

Purlin Production Line



Note. From the Modern Steel Company

To remain competitive in the current steel building construction market, the company needs to develop a competitive advantage by considering continuous improvement to reduce overall production costs. Understanding possible hidden factors throughout the entire process is a fundamental requirement for achieving continuous improvement in business processes. Therefore, producing quality products and fostering a continuous improvement mindset can strengthen the company's competitiveness in the long term.

Aims

The objective of this case study is to reduce the scrap rate of purlins from 3% to 1%, in line with the company's target. This study demonstrates how the DMAIC methodology can be applied systematically. The approach involves defining the problem, developing and executing a nine-month data collection plan, analyzing the collected data to identify root causes, and implementing improvement actions along with a control plan. Finally, similar problems in the purlin production process should be prevented from recurring in the future.

Literature Review

Nowadays, Lean principles and the Six Sigma approach have been integrated to help organizations achieve process improvement and are called Lean Six Sigma (LSS). The LSS approach applies Lean concepts to reduce waste and speed up processes, while the Six Sigma concept helps identify potential areas for improvement by relying on data and facts and applying systematic thinking through the DMAIC steps (Smutkupt, 2022). Therefore, the LSS approach is used to systematically analyze the root causes of problems, identify sources of variation, and reduce waste in manufacturing processes. Moreover, LSS is one of the most popular tools used to help organizations succeed in improving their processes, thereby enhancing customer satisfaction and achieving financial savings (E.V. et al., 2019). To deploy LSS, the five phases of DMAIC must generally be followed: Define, Measure, Analyze, Improve, and Control. Implementing DMAIC ensures that organizations can address the root causes of problems, enhance productivity and profitability, and apply the appropriate process execution strategy (Soet, 2022).

LSS can be applied not only in manufacturing but also in service business such as education and IT. Many researchers have applied LSS and DMAIC approach to address quality issues. For example, the study by Soet (2022) demonstrates how processes can be streamlined and systematic thinking promoted to reduce defects in coffee beans in Myanmar. By applying the five steps of DMAIC, the company successfully identified the root causes of defects and enhanced its coffee production process, which in turn improved customer satisfaction, lowered costs, and boosted profitability. After implementation, the defect rate significantly decreased, dropping from 25.09% to 9.83%. The study of Oliver et al. (2019) reveals that applying LSS can improve the grading process. The result shows that there was a significant reduction in grading cycle time which directly addressed the instructor's frustration.

DMAIC (Define-Measure-Analyze-Improve-Control) Methodology

The Six Sigma DMAIC framework serves as a structured approach for problem-solving and improving products or processes. Most organizations adopt Six Sigma by first applying the DMAIC methodology (GIRMANOVÁ et al., 2017). The Define phase aims mainly to construct the statement of the problem, the objective of the project, and develop the goal of the project by ensuring that the project is focused on a viable business problem or pain point. By clearly defining the problem, the scope of the project can be narrowed down to increase focus on the focal point of the problem. The project charter, which is a written explanation of the present state of the process must be completed during the Define phase (Jacobson & Johnson, 2006). Moreover, a project charter provides a detailed road map for a project, clearly defining the problem to be solved, the expected outcomes, and the project's timelines (Erdil et al, 2018).

The Measure phase, as the second stage, involves collecting data to confirm and assess problems as well as opportunities (Astini & Imaroh, 2021). It encourages people to make decisions based on data and fact. In addition, the Measure phase is about clarifying the existing performance of the process and the degree of providing the business requirements. Check sheet, observation, in-depth interview, and process flow chart are the tools and techniques used at the Measure phase to evaluate possible causes.

Furthermore, the main task of the Analyze phase is to identify the possible root cause of the problem and then track down the real root cause. In other words, the data gathered during the Measure phase will be used to identify the fundamental cause that needs to be addressed. This is a data-driven approach to figuring out what is causing the problem. Consequently, assuming the root cause without proper analysis leads to making the wrong decision and exhibiting the problem. Applying the appropriate statistical tools and techniques, such as Pareto analysis and Cause and Effect analysis can be done in this phase (Hessing, 2015).

The goal of the Improve phase is to identify and prioritize the list of improvements. In other words, developing an implementation strategy, performing a pilot project, and assessing the solution's effectiveness. More importantly, the Improve phase is to provide the differential diagnosis that is formulated for a real cause in which outputs are truly a result of the inputs and not just a possible correlation that could happen by chance. If one knows how the output changes with the inputs, one can adjust the input accordingly with a methodical understanding of the process (Zebovitz, 2017). In addition, a variety of techniques and concepts are suitable such as brainstorming and developing a reaction plan.

Control is the final phase, playing a crucial role in sustaining the improvements achieved in earlier stages. Its main objective is to monitor and preserve the results gained throughout the Define, Measure, Analyze, and Improve phases. Control entails defining metrics and standards to evaluate the success of improvements, while also implementing systems to sustain, track, and enhance the new process over time. The control phase also helps to highlight potential areas where changes might cause negative effects. Through continuous monitoring and evaluation of the new process, organizations can promptly detect issues and implement corrective measures before they escalate (Stern, 2023).

Smetkowska and Mrugalska (2018) stated that the Control phase examines the quality of the process improvement made during the Improve phase. It also monitors the future state of the process to ensure that deviations from the target are minimized and corrected before having a negative impact on the outcome of the process.

Several researchers and practitioners have implemented DMAIC effectively and successfully. For instance, Jirasukprasert et al. (2014). showed the achievement of improving the production process and product quality of rubber gloves manufacturing with the implementation of the DMAIC technique of the Six Sigma methodology. Defective leaked gloves were effectively decreased by roughly 50% after implementing process improvement to eliminate variables in the present process. In addition, (Chartmongkoljaroen et al., 2019) identified the problem as a high rate of resin defects in the modeling department of a jewelry manufacturer. This problem has been successfully solved by applying DMAIC, such as analyzing and determining the source of the defective resin, improving the modeling process, and reducing the resin failure rate. Through the research, the company has reaped the benefits of significantly increasing the number of single-printed resins from 17% in 2018 to 42% at the end of Q2 2019, which has allowed the company to reduce defect rates of resin as well as improve modeling processes.

Related Tools

Various quality tools are applied throughout DMAIC phases in this study and are explained as followings. The check sheet is a basic and effective tool that comes in handy while working on Six Sigma initiatives. It is a tool designed to simplify data collection for specific objectives and to present the results in a clear format that can be easily transformed into useful information (Astini & Imaroh, 2021). Moreover, the observation is usually done during the project's Measure phase, based on a fundamental understanding of the process gained during the Define phase. A fundamental framework of observation must include what to observe, when to observe, and how often to observe, which is to cover all control aspects of the process. The team of observers is arranged according to the process's complexity, and all team members must be well informed on the processes and framework for observation activities (Arumugam et al., 2012).

In-depth interviews with people involved in the process are one of the techniques used to collect data and information about causes and their consequences (Chartmongkoljaroen et al., 2019). In-depth interviews can provide additional information, making it easier to instantly select the most important facts (Guest et al, 2018).

A process flow is a tool that identifies the inputs, outputs, and various elements influencing a process. It illustrates the sequence of products, documents, operator tasks, or administrative activities. Typically, process flow serves as the foundation for improvement initiatives, helping to highlight unnecessary complexity, duplication, or redundancy, while also providing insights and ideas for process enhancement (Salmon, 2017). For instance, Kuaiteset al. (2020) demonstrated that using a process map made the entire workflow more transparent, allowing delays, bottlenecks, and errors in the steps to be clearly detected.

A Pareto chart is a graphical tool for categorizing and organizing problems into categories depending on the degree to which the problems have an effect. From the most important to the least important, rank the problems. It aids in narrowing the breadth of the problem and increasing the emphasis on the problem that has the greatest impact (Summers, 2006). Cause and Effect diagram is a problem-solving method that identifies probable root causes. It is also known as the "Ishikawa or Fishbone diagram." It shows the links between all of the variables and their outcomes. Cause and Effect diagram is also a useful tool for quality management and problem-solving, such as identifying the causes of problems or failures in the existing process through brainstorming, developing ideas, and receiving information from the team or other stakeholders (Chartmongkoljaroen et al., 2019; GIRMANOVÁ et.al, 2017).

Brainstorming is one of the techniques in Improve phase for coming up with a lot of innovative ideas in a short amount of time. It is high-intensity, fast-paced, and synergistic, resulting in a large number of ideas that can be distilled down or channeled down to a smaller number of priority topics thereafter. When organizing a brainstorming session, it is critical to spell out the actual issue. The ideas are categorized, rated, and follow-up activities are agreed upon by the group after the meeting (Hessing, 2013).

Daily performance review meetings can be used to address and discuss short-term operational difficulties between department heads or managers and the teams that report to them. The common subjects on the agenda include the "hot concerns" of the day, specific operational performance difficulties, or project performance. Daily performance reviews force everyone to realize that the meeting is about active and quick problem solving so that it is not passive listening (Kaplan & Norton, 2008).

Gemba walks are characterized as heading to the reality of the activity. "Gemba" is a Japanese word that signifies "the real thing" or "the real place." The Gemba is the most crucial location for a team since it is where the actual work takes place. Managers may find the Gemba walk to be a useful tool for identifying process improvement opportunities and driving alignment throughout an organization. Regularly conducting Gemba walks can have a number of benefits, including establishing stable relationships with employees who do the work and create value; identifying problems and taking actions for continuous improvement much more quickly; and clearly communicating goals and objectives, all of which can lead to increased employee engagement (Nestle, 2013; Raut & Kumar, 2017).

In addition, the visual process management is the communication aid that effectively drives operations and processes in real time. Graphical presentations, pictures, posters, schematics, symbols, transparencies, and color coding are some of the most effective visual aids. These are effective strategies to interact with others in order to prevent unpleasant situations and respond before they occur. The advantage of visual process controls is that they provide the information quickly and easily to understand, which improves communication and keeps the flow running smoothly and consistently (Parry & Turner, 2006).

Research Methodology

This study has applied DMAIC approach which includes Define phase, Measure phase, Analyze phase, Improve phase, and Control phase. Under Define phase, the Purlin can be defined as main products of Modern Steel company which is highest production tonnage (687 tons) as well as highest scrap tonnage (22 tons) compared to other products. The goal of this research project was to reduce the scrap percentage from 3% to 1% as per company target. The improvement project will focus on cold roll forming activities of purlin production line. The detailed steps of each phase were conducted.

Define phase

The Define phase of this research focused on refining the problem of Modern Steel Company to increase the emphasis on deficiency within the process or actual problem. The problem is defined as the defect rate of the purlin production of 3% is higher than the control target rate of 1% that increase the cost of goods sold (COGS). The project was focused on the cold roll forming activities of the purlin production line, which included raw material feeding to the machine line until packaging and storage of finished goods.

Table 1

Project Charter

Project Name	Reduction of scrap rate of purlin production line
Problem Statement	Scrap rate from purlin production was 3% and it is higher than the control target. The 3% of purlin scrap which is equivalenced 22 tons of raw materials and it made loss 33 million Myanmar Kyat (MMK).
Business Case	Improve the spread margin to 30% of the revenue by reducing COGS which is cost of scrap from the purlin production. Spread margin = Revenue – Raw material costs
Goal Statement	To reduce the scrap rate of purlin to 1% as per target of the company
Project Scope	Focus on all the production steps of purlin production including raw material feeding to machine line until packaging and storage of finished good products.

Table 1 illustrates the project charter which was developed to provide a better understanding of the project by addressing the specific problem, sufficient impact on business, the boundary of the project, and the expected result from the improvement project. The project charter is used to communicate key project details to all concerned parties within the company, ensuring that the scope and objectives of the study are agreed upon by everyone involved.

Measure Phase

Modern Steel Company found the high scrap rate at the purlin production line as the problem. To find the root cause of the problem, the required data were collected from integrating sources, such as check sheets, observations in the production facility, and in-depth interviews with stakeholders involved in the production process, such as machine operators, production coordinators, quality controllers, maintenance technician, and production supervisor. While conducting data collection, operational definitions of the required data and the data collection process were developed and monitored by supervisors

Four different check sheets used in the production line to record the production-related data are included Production time record, Finished goods record, Raw materials consumption, and Quality inspection forms. Production time record is used to identify the uptime and loss time within the production activities, and data were recorded daily by the machine operator. Finished goods record is used to collect the products produced in accordance with the production orders and completion status of production orders. This record was documented by the operator for each production order, and the production supervisor reviewed and approved the recorded data. Raw materials consumption record is a scrap record from the production process, in which the data were collected by the production coordinator for each raw material coil that was used for production, and raw materials were issued by the production planner. Scrap can be classified based on the effect of the products. Quality inspection form is a document used for the recording of inspections for product quality. The operator and the production coordinator inspected the quality of the products at a specific frequency as set by the quality control team, and data on the quality of the finished product were recorded with a quality inspection. A quality inspection was carried out based on four key criteria, such as the standard dimension of the raw materials coil, the physical appearance of the raw materials coil, the standard dimension of the product, and the physical appearance of the product.

Furthermore, the observation in the production facility is designed and carried out to understand the actual actions that are carried out by stakeholders in the production process, and the observation includes the practices of data recording, normal process routines, and problem-solving methods when issues occur. Observation can reveal the gap between work instructions and actual process practices. Gaining insight into this gap will aid in identifying the causes if stakeholders in the production process are not carrying out their duties in accordance with the instructions provided. Observation in the production facility is carried out and recorded on the observation form. An observation form is included to record the operation name, operator's name, name of machine line, which is observed, date of observation, and shift of operation, which is observed and signed by the production supervisor as an acknowledgment for observation.

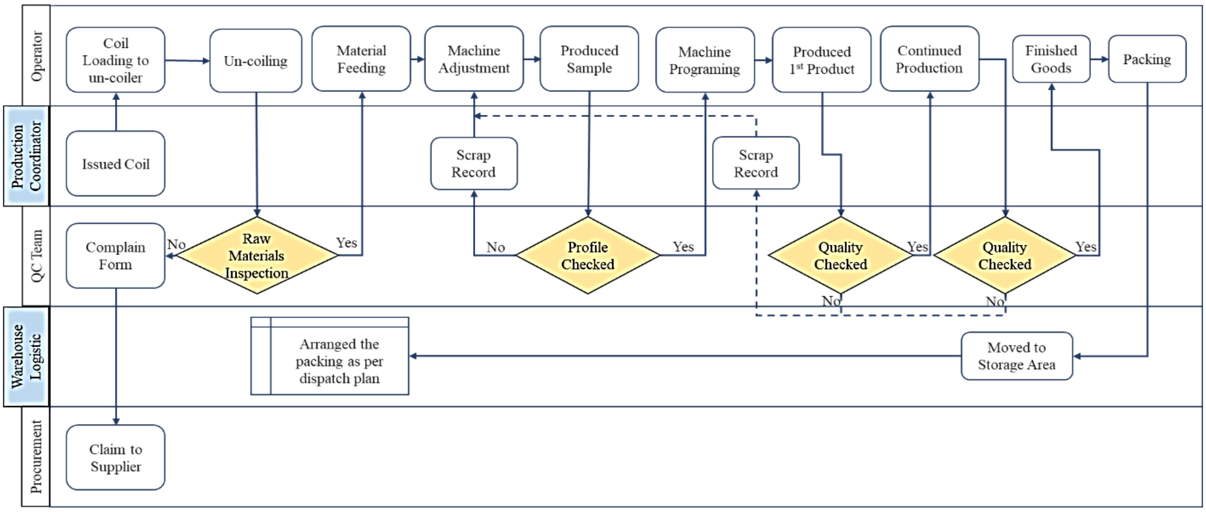
In-depth interview with stakeholders gives understanding of the details of actual practices in the production process, the constraints within the production process, and the practices of countermeasures when faced with problems of occurring scraps during the time of production. Concerning observations made in the production facility and an in-depth interview, the author prepared the flow chart for further study to understand the process characteristics and key parameters of the cold roll forming process of purlin production.

Figure 2 discloses a detailed explanation of the activities of stakeholders in the production process and process sequences. It represents all the operational activities or steps starting from raw materials issuing until the end operation, like packing and storing finished goods. Moreover, figure 2 also reveals the six conditions in the production process that have the probability of occurring the product scraps.

First, the requirement of producing a sample piece of product with a maximum length of 1500mm to check the profile and record as scrap, whether it passes or fails the inspection in accordance with the quality standard. Second, the requirement of readjusting the material feeding guide and roll forming roller until the profile of the sample product is in accordance with the standard requirement. Third, inspection is required for the first pieces of product that are produced in accordance with the production order, and the product can be rejected if it does not meet the quality standard. Fourth, it requires readjusting the material feeding guide, roll forming roller, and machine's program until it obtains the first pieces of the product in accordance with the standard requirement and production order. Fifth, in-process quality inspection is required when completing the defined quantity as per quality inspection procedure or production order, and products can be rejected if they do not meet the quality standard. The sixth requires readjusting the material feeding guide, roll forming roller, and machine's program until the products are obtained in accordance with the standard requirement and production order.

Figure 2

Purlin Production Process Flow



Note. From the Modern Steel Company

Analyze Phase

The Analyze phase of this research reviewed the collected data and identified the cause of the problem by applying Pareto analysis and Cause and Effect analysis. The Pareto analysis was used to review and figure out the significant problems which obtained from the check sheets.

According to the data collected during the Measure phase, scrap from the purlin production line was recorded with nine different classifications, as shown in Table 2 Moreover, Figure 3 illustrates the pareto of scrap types that were significantly affected and required focus to find the root cause. As a result, there can be identified significantly affected of 85% (18 tons of scraps) with three classifications (L08-Profile Out, L15-Wrong Length, and L33-Scrap from Cutback).

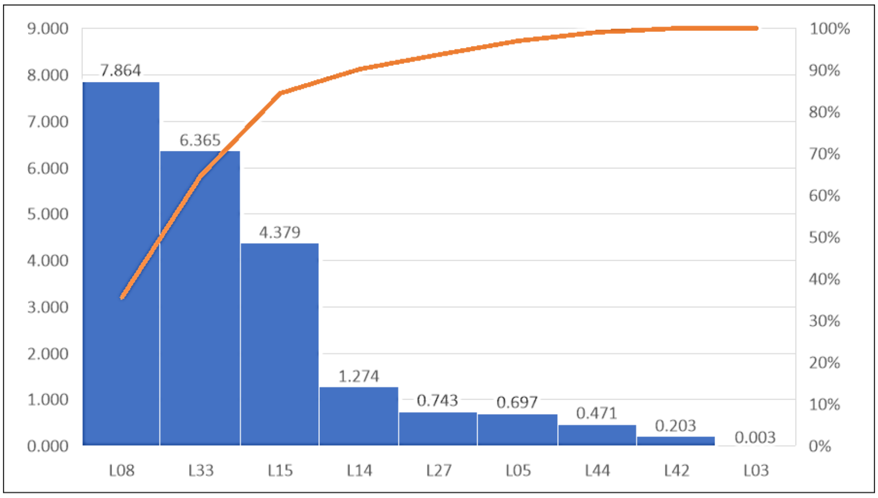
Table 2

Scrap Types with Quantity (9 Months)

Code	Code Descriptions	Qty (Tons)
L03	Scratches	0.003
L05	White Rust	0.697
L08	Profile Out	7.864
L14	Punch Hole Out	1.274
L15	Wrong Length	4,379
L27	Testing	0.743
L33	Scrap from Cutback	6.365
L42	Scrap - First Piece Cut-Off	0.203
L44	Machine Fail	0.471
Total		**22.000**

Figure 3

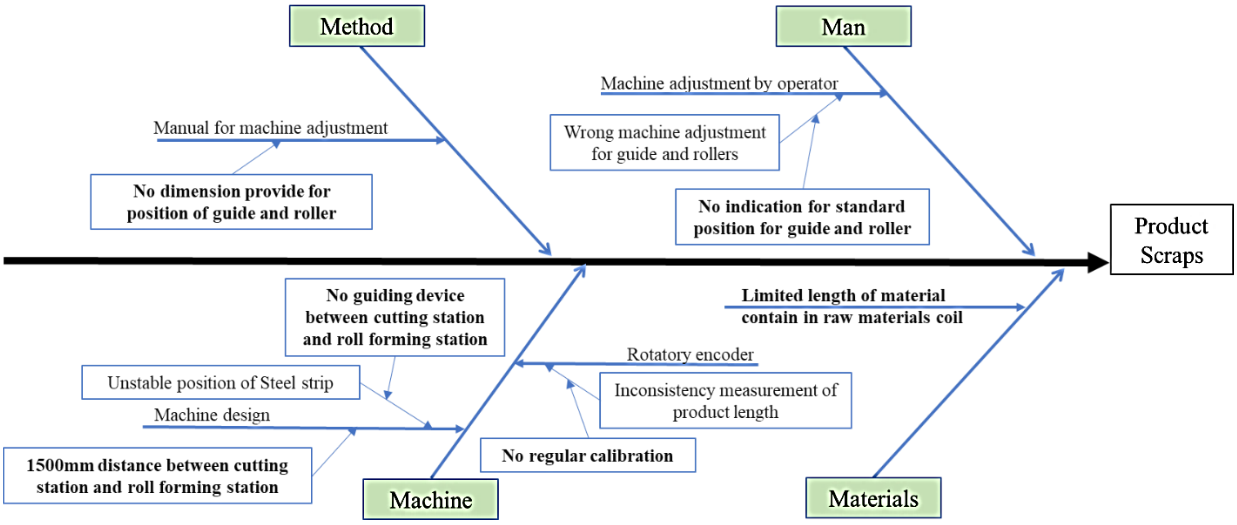
Pareto of Scrap Types



In addition, Cause and Effect analysis or Fishbone diagram as shown on Figure 4 was conducted based on the 4M (men, machine, material, and method) concept and its collaboration between data from observation on the production floor and in-depth interviews with stakeholders in the production process and various check sheets. Moreover, the Fishbone diagram provides an understanding of the root causes of scrap occurrences and supports identifying actions to prevent similar issues from recurring.

Figure 4

Cause and Effect Diagram



The L08-Profile out, which is a product's dimension was out of tolerance. This cause occurred for three main reasons. First, the indicator for the standard position of the feeding guide forming roller was not available at the machine. Second, the dimensions for the standard position were not available in the operation manual. As a result, the operator adjusted the machine based on their own experience without standard reference or instruction, resulting in incorrect positioning of guides and rollers and missed shaping or forming of the products. Third, an inappropriate machine design, which did not have a guide between the cutting station and the roll forming station. It was caused by the instability of the steel strip after the cutting station and a missed alignment of the steel strip when starting the roll forming of the product.

L33-Scrap from cutback which occurred due to two main causes. First, is the requirement of additional materials for the products with a length less 1500 mm. The machine was designed at a 1500mm distance between two driving rollers to produce the product with a minimum length of 1500mm. The function of driving rollers is the moving of steel strips in a roll-forming machine. Therefore, additional materials are required to add when producing the product with less than 1500mm and cut out the extra length after the production as a scrap product. Second, the limitation of length in raw materials coil made the extra materials after the production based on the production order. Those extra materials could not be used for other production orders due to insufficient reaming length and become scrap materials.

L15-Wrong length occurred due to inaccuracy measurement of product length with a rotary encoder. A rotary encoder is an electro-mechanical device known for its ability to provide real-time position information that converts the distance moved of materials to digital output signals. The length of the product is measured by the rotation of the rotary encoder's wheel. A steel strip went through under the wheel of the rotary encoder.

Improve phase

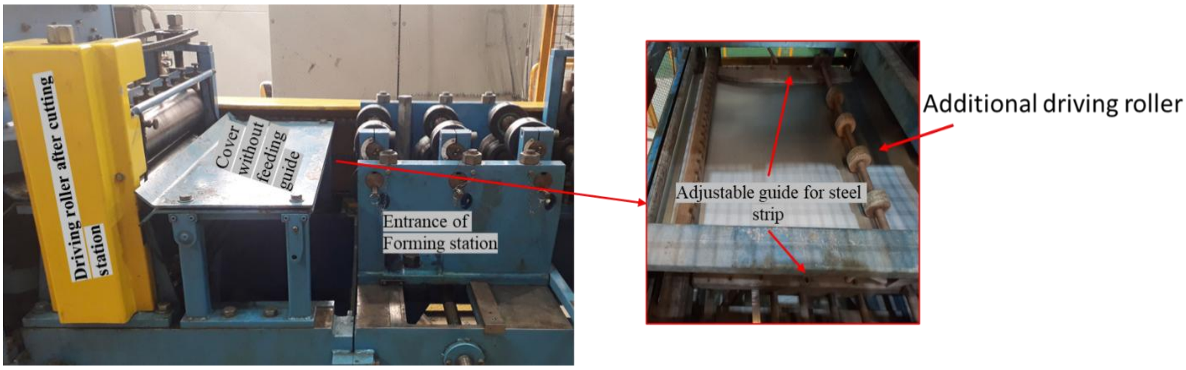
After having a clear understanding of the problem and identifying the root causes, the author facilitated the brainstorming session to develop the most effective solutions as well as an improvement action plan for eliminating or reducing the incidence of the three classifications of scraps (L08-Profile Out, L15-Wrong Length, and L33-Scrap from Cutback) in the purlin production process. The brainstorming session involved the stakeholders of the production process, such as the HSE officer, production supervisor, maintenance engineer, production planner, and senior operators.

After the session, the team confirmed the improvement actions as follows, and implementation was completed. The solution to L08-Profile out can be described as the improvement of tools for machine adjustment and machine modification. The new tools for machine adjustment can help operators position the guide and roller easily and accurately based on the type of product to be produced. The correct adjustment of the guide and roller before insertion of the steel strip is required to minimize such incidents of the wrong positioning of the steel strip into the machine. The insertion at other different positions into the machine, all in all, can mis-dimension the product due to poor alignment of the steel strip during the forming process. The solution was also designed to address problems driven by human errors, such as missing the position of the guide and roller while inserting the steel strip into the roll forming machine.

For every state in the roll forming process, the alignment and positioning of steel strips in the roll forming machine are very important to get the correct dimension of the product. According to the problem formed, the steel strip was misaligned or mispositioned when inserted into the roll forming station due to the material feeding guide being missing between the cutting station and the roll forming station. To solve this problem, an additional guide was installed between the cutting station and the roll forming station. Figure 5 illustrates the machine modification as installation of additional guide to maintain the position and alignment of the steel strip when it is inserted into the roll forming station.

Figure 5

Machine Modification – Adding Guide and Driving Roller



The solution to the problem L33-Scrap from cutback can be explained as the condition that an additional driving roller is installed to support the steel strip with a short length (500 mm) while being passed through into the roll forming station. This solution can be supported to minimize the scrap from extra materials at the end of the coil by producing the products with a short length as a stock of finished good products. Figure 5 also illustrates the additional driving roller to support the steel strip as it goes through the roll forming station.

The solution to the problem L15-Wrong length is to carry out the routine calibration process for rotary encoders to make sure that the measurement of product length is consistent and accurate while making mass production. According to the recommendation of the Original Equipment Manufacturer (OEM), calibration of a rotary encoder is done for every 500,000 meters of production as an onsite calibration service by the third party certified technical team.

Control phase

A control plan has been developed after the improvement actions to maintain the continuous improvement and make sure the performance results based on the improvement have been monitored carefully and consistently. The control actions of daily leadership and management, which include the activities of the daily performance review meetings, Gemba walk, and virtual management tools, have been put in place to monitor and control the process performance.

The daily performance review meeting is led and facilitated by the production manager, who provides direction and prioritization and ensures a timely meeting. The best practice is to have a fixed time for the meeting (e.g., no longer than 60 mins). Daily review meetings are held in an established standard agenda and dedicated meeting area and are attended by a nominated group of stakeholders, such as safety officers, production supervisors, production planners, quality controllers, maintenance engineers, and subject matter experts, or their representatives with delegated authority.

Daily review meetings always start with a review of the last 24 hours' safety and environmental performance, which is monitored and presented by the safety officer. After the safety performance is reviewed, the last 24 hours of production performance, such as machine uptime, production volume, productivity, and scrap rate, are reviewed against targets and progress to plan with the support of visual management tools, which are monitored and presented by the production supervisor.

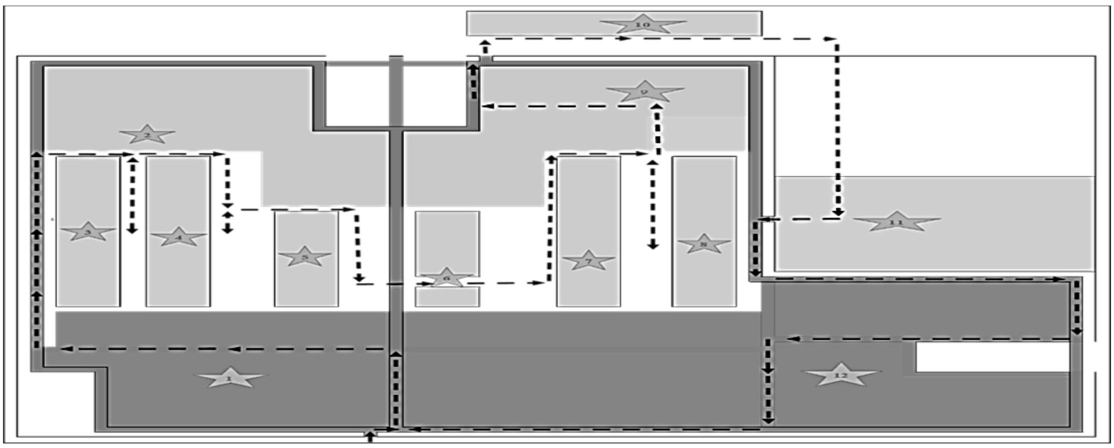
After reviewing the production performance of the last 24 hours, they conduct the critical checks, which include the quality performance by the quality controller and machine performance by the maintenance engineer. At the end of the daily performance review meeting, the production planner presents the production plan for the next 24 hours. Attendees are to provide an update on the resolution of issues or advise the production manager that the problem is not yet resolved, and actions have been assigned to the right people for follow-up during the day. Clear ownership of issues is understood, actions captured, and available to non-attendees with feedback available to the originator.

Digitalized and online event reporting system/software available to all employees. This is an electronic system that captures the issue or event. Follow-up actions are assigned to individuals, and feedback from the follow-up officer is available to everyone. Regular review of outstanding actions and follow-ups occur as a weekly or monthly review of outstanding actions from daily review meetings to ensure the outstanding actions list does not get out of control.

Gemba walk is carried out by daily routine and involves key stakeholders such as the production manager, production supervisor, quality controller, and shift team leader. A map for walking and a checklist were created to document the daily Gemba walk routine as shown in Figure 6. Every day, a Gemba walk on the production floor is organized by following the morning block review session of the production manager. The team would choose one of the key themes, such as productivity improvement, cost-saving, reduced scrap, facilitating improvement ideas, etc. Moreover, various visual process management tools have included a combination of performance metrics (e.g., machine uptime), product attributes, critical process, and equipment variables, as well as leading, lagging, and product indicators.

Figure 6

Map for Gemba Walk



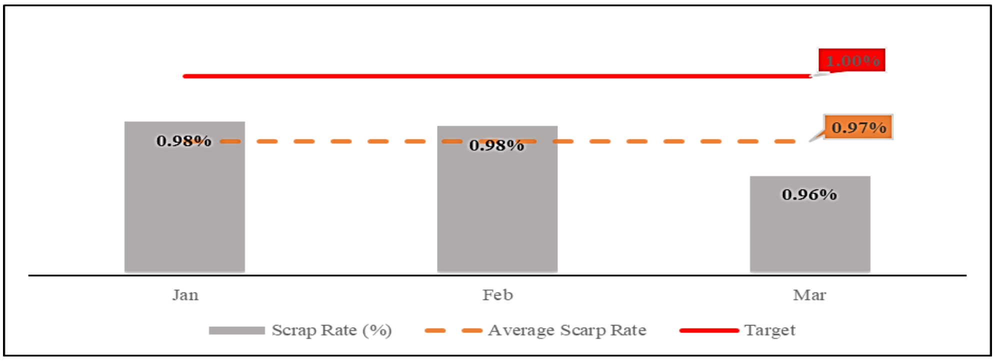
Control limits for each performance are defined and a visual dashboard for machine uptime, asset utilization rate, production run charts, and leading indicators for critical equipment is displayed in the daily review meeting room and a location within the department accessible to all employees. Leading indicators have control limits defined, which support the action that can be taken before a quality or equipment issue develops. The visual management dashboard is owned by the production supervisor and updated before the commencement of the daily review meeting. It is updated regularly, with up-to-date information being available to all attendees before the meeting. Another purpose of visual management display is as a focal point for the business improvement process to provide recognition and encourage involvement that relentlessly drives to reduce all forms of waste.

Results

The result of scrap quantity from purlin production has been decreased from 3% to 1% after the completion of improvement actions, and it achieved the target of the company as shown in Figure 7. Moreover, ninety-four (94) tons of finished goods were produced, and the scrap quantity was 0.93 tons within three months. Table 3 compares the types of scrap and their quantities before and after the improvement actions. Production data were collected with the same methods as before the improvement actions.

Figure 7

Scrap Rate of Purlin (%)



The Modern Steel Company has made significant improvements by reducing the majority of scrap, which comes from L08-Profile Out, L15-Wrong Length, and L33-Scarp from Cutback. Furthermore, the company can avoid revenue loss by eliminating the unnecessary cost of losing raw materials such as scrap. The results have shown a positive outcome after adopting DMAIC Methodology. This methodology effectively supports the performance improvement of Modern Steel Company.

Table 3

Scrap Types with Quantity Before (9 Months) Vs After Improvement (3 Months)

Code	**Code Descriptions**	**Qty (Tons)** (Before)	**Qty (Tons)** (After)
L03	Scratches	0.003	0.14
L05	White Rust	0.697	0.00
L08	Profile Out	7.864	0.20
L14	Punch Hole Out	1.274	0.00
L15	Wrong Length	4.379	0.18
L27	Testing	0.743	0.16
L33	Scrap from Cutback	6.365	0.07
L42	Scrap- First Piece Cut-Off	0.203	0.09
L44	Machine Fail	0.471	0.09
Total		**22.000**	**0.93**

Conclusions and Discussion

Define-Measure-Analyze-Improve-Control (DMAIC Methodology) was applied in the study to reduce the scrap occurrence from the purlin production process of Modern Steel Company, which is a manufacturer of steel building products. Referring to the result of this study, Modern Steel Company successfully solved the problem and achieved the target by reducing the scrap rate from 3% to 1% as per company's target.

The DMAIC Methodology is a systematic and logical approach to the problem (E.V. et al., 2019). It helps to gain a better understanding of the process by analyzing deeply and identifying the actual root cause of the scrap based on data and facts (Astini & Imaroh, 2021; Soet, 2022). Furthermore, by allowing employees at all levels to participate, the DMAIC technique can propose the best solution for the problem. When the solution is identified, the improvement actions are implemented and controlled by the process to sustain the improvement and prevent it from reoccurring in the future (Stern, 2023).

The DMAIC Methodology was used in this study by applying the various tools to each stage. The technique structurally defines the problem by developing the project charter. The project charter provides the detailed road map for a project, which is incorporated into four critical components, such as the impact on business, the statement of the problem, the goal of the project, and the project scope. Logically measuring the problems supports making decisions based on facts and reality (Erdil et al, 2018). This can be used to officially communicate project information to the concerned parties.

By analyzing the data, it can identify the exact root causes of those problems and gain a better understanding of variables and factors. In addition, it helps to develop the improvement actions based on the root causes and recognition of the control plan to avoid the problem from reoccurring in the future (Smutkupt, 2022; Soet, 2022). In addition, this methodology allows employees in associated parties of the company to collaborate more effectively by exchanging ideas, brainstorming to find the fundamental causes of problems, and producing solutions (Chartmongkoljaroen et al., 2019; Hessing, 2013; GIRMANOVÁ et.al, 2017). The participative involvement and driving force of the management team is one of the success factors for the implementation of the DMAIC technique in the company. The whole project team actively participated to obtain a positive result from the implementation of improvement actions and maintain the result as a sustainable improvement.

To maintain improvements and prevent problems from recurring, control actions such as daily performance review meetings and Gemba walks have been implemented. The Gemba walk on the production floor is conducted after the morning block review session led by the production manager. This practice enables managers to build strong relationships with employees, identify issues, and take corrective actions for continuous improvement more effectively (Raut & Kumar, 2017).

However, this study has some limitations. The business nature of Modern Steel company is providing the service from design solution, supply materials and construct the build according to customer requirement. Therefore, Modern Steel company use the make-to-order manufacturing strategy, it's also known as High-Mix-quantities. Make-to-order manufacturing Low-Volume (HMLV) manufacturing strategy, is the process of producing difference kind of products in limited requires high level of feasibility to adapt the frequently changes in jobs, materials, and machines with wide range of product requests. In Make-to-order manufacturing environments, constantly change in scheduling of jobs and large different type of materials use for production, which can often lead to impact on the consistency of data collection and accuracy of data analysis. For example, producing the same shape and length of purlin with different material thickness, weight of both product and scrap in tonnage is difference.

Suggestions

This improvement project had to be completed and data collected within a short period of time (3 months); therefore, a daily performance review was introduced. However, a long-term control plan should be developed and implemented. Such a plan needs to align with the organization's long-term quality management strategy, such as deploying Lean Six Sigma to streamline processes and integrating high technology to prevent defects.

Moreover, the organization can explore Manufacturing 4.0 technologies and align its operations with the principles of this concept. Integrating Lean Six Sigma (LSS) with Manufacturing 4.0 is essential for organizations aiming to capitalize on diverse interactions and harness advanced technologies to enhance employee development. Moreover, LSS tools can streamline the implementation of Industry 4.0 technologies and foster sustainable innovation in manufacturing.

Deploying a systematic approach (DMAIC) has proven that using data and facts to address problems can effectively solve root causes and prevent their recurrence in the future. Besides manufacturing, the DMAIC methodology can be applied not only in production but also in service industries such as education, healthcare, and government services. Many interesting areas in the business world might be enhanced to achieve greater benefits, such as flexible capacity, waste reduction, ongoing product and service enhancement, and increased efficiency

In addition, this case study demonstrates the application of the DMAIC methodology to reduce defects in the steel industry in Myanmar. The approach can also be systematically adopted by other steel companies operating in similar environments within the country to reduce defects and implement various tools for continuous improvement**.**

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