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Research Article

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SMED Techniques for Rapid Setup Time Reduction in Electronics Industry

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Abstract This study delves into the application of Single-Minute Exchange of Die (SMED) techniques for rapid setup time reduction within the electronics industry. Setup time, often a bottleneck in manufacturing processes, significantly impacts production efficiency and overall operational effectiveness. Through a detailed examination of SMED implementation in an electronics manufacturing setting, this research elucidates the specific techniques employed to streamline changeovers and minimize downtime between production runs. By leveraging SMED methodologies, such as separating internal and external setup activities, converting setup tasks to external operations, and standardizing procedures, the study showcases tangible improvements in setup time reduction and operational agility. Results indicate substantial reductions in set-up times, leading to enhanced productivity, increased throughput, and ultimately, improved competitiveness within the electronics manufacturing landscape. The findings underscore the significance of adopting SMED principles as a cornerstone for achieving operational excellence and sustaining long-term success in the dynamic and demanding electronics industry.

Keywords Agile Manufacturing, Operational Improvement, Bottleneck, Quick Changeover.

Introduction

In the realm of contemporary manufacturing, the pursuit of operational excellence and heightened efficiency has become paramount for businesses striving to meet evolving market demands. One of the critical aspects influencing production efficiency is the duration required for setup or changeover activities, often identified as a major contributor to non-value-added time in manufacturing operations. In this era of modern manufacturing, where agility, efficiency, and responsiveness are paramount, the reduction of setup time stands as a critical imperative. The electronics industry, characterized by rapid technological advancements and ever-changing consumer demands, faces unique challenges in achieving swift changeovers between production runs. Setup time, encompassing the preparatory tasks required to switch from manufacturing one product to another, represents a significant portion of non-value-added time within production processes. Prolonged set-up times not only impede production efficiency but also limit a company's ability to respond quickly to market demands, potentially resulting in lost opportunities and diminished competitiveness. Recognizing the pivotal role of setup time reduction in enhancing operational efficiency, the concept of Single-Minute Exchange of Die (SMED) emerges as a beacon of hope for manufacturers seeking to optimize their production processes. Developed by Shigeo Shingo, a prominent figure in the lean manufacturing movement, SMED offers a systematic approach to minimize setup times to the extent that changeovers can be accomplished in mere minutes - or, as the name suggests, within a single-digit number of minutes. In this context, this study endeavors to explore and analyze the application of SMED techniques for rapid setup time reduction within the electronics industry. Through a comprehensive investigation, we aim to elucidate the specific methodologies, tools, and strategies employed to streamline changeovers and enhance operational agility. Some researchers try to find human interaction system development using biomechanical processes, especially in workforce design from which we have adopted our ergonomics factor [18]. By delving into real-world case studies and industry best practices, this research seeks to uncover the underlying principles and mechanisms driving successful SMED implementation in electronics manufacturing settings. Their suggested method offers a structured process for choosing the most suitable setup technique from various options, while also considering additional factors influencing the decision-making process. These factors encompass cost, energy consumption, facility layout, safety measures, equipment lifespan, product quality, and maintenance requirements. To illustrate this approach, a practical case study from the PVC industry is employed as an example. The findings from this case study highlight the effectiveness of the proposed method in reducing setup times. Consequently, this improvement is expected to enhance machinery utilization, boost overall productivity, and augment the flexibility of the entire facility [6]. Some studies place significant importance on shifting internal activities to external ones wherever feasible, while also striving to minimize internal tasks. The primary outcomes of the research reveal that setup times for the turning line were reduced by over 45%. As a result, the application of the SMED method has the potential to substantially enhance machine capacities [7]. Furthermore, this study aims to quantify the tangible benefits accrued from SMED adoption, including but not limited to increased productivity, reduced downtime, enhanced flexibility, and improved resource utilization. By shedding light on the transformative potential of SMED techniques, this research aims to provide valuable insights and actionable recommendations for electronics manufacturers striving to achieve operational excellence in today's fast-paced and competitive market landscape. Biswas et. al. (2024) describes in her research how Production can be improved by using different IE tools in the factory and how risk management is also mitigated by using several criteria [9,10,11]. Companies can streamline their inventory levels by producing precisely what customers require, promptly shipping goods after production. They examine the changeover process across various operations to assess the suitability of implementing the Single Minute Exchange of Die (SMED) technique. It also identifies various factors contributing to unnecessary changeovers and their effects on production cycle time. The findings indicate a reduction in tool and die changeover time from 34.24 minutes to 11.91 minutes, representing a decrease of 22.33 minutes. Moreover, productivity increased by 65.28% because of these improvements [19]. This not only minimizes storage costs by reducing the reliance on warehousing but also lowers handling, transportation, and obsolescence expenses. High inventory levels correlate with slower turnover, posing a greater risk of obsolescence and increased likelihood of damages during storage and handling, leading to potential scraps or rework. Smaller lot sizes contribute to a higher product assortment and improved quality, along with shorter delivery times, culminating in increased customer satisfaction. Additionally, by reducing costs, companies have the option to deliver greater value to customers through lower prices, heightened satisfaction, and an expanded market share. However, it's essential to note that frequent setups accompany smaller lot sizes. Consequently, an operation with extended setup times, spanning several hours, may face challenges in adopting a small lot size approach, as the time allocated to setup activities could offset the benefits of the approach itself. Lean manufacturing stands as both a philosophy and a set of practices committed to the eradication of waste and variability across all business processes. In this context, waste is defined as anything that adds cost without providing value from the perspective of the end customer. Widely embraced on a global scale, lean manufacturing has become one of the most prevalent and adopted production philosophies. The success and widespread adoption of lean manufacturing can be attributed to influential publications, with two notable books playing a pivotal role: "The Machine That Changed the World" (Womack et al., 1990) and "Lean Thinking" (Womack and Jones, 1996) [1]. These seminal works not only define the principles of lean manufacturing but also introduce a range of tools and techniques integral to its implementation. A standout methodology within the realm of lean manufacturing tools is the Single Minute Exchange of Die (SMED). This systematic approach is designed to methodically reduce the setup time of operations, aiming to transform it from a lengthy process spanning hours to a more efficient timeframe of minutes. SMED, as part of the lean manufacturing toolkit, contributes to the overarching goal of enhancing operational efficiency by minimizing non-value-added time, aligning with the core tenets of lean philosophy. Molla et al. (2024) undertake a comprehensive investigation to determine how TPM technology helps in production for operational improvement through TPM technology and they show it meticulously for electronics industry set-up. The insights gleaned from these studies not only contribute to the enhancement of production processes but also align with our broader goals of promoting safety and efficiency in manufacturing environments, ultimately fostering a rich learning experience for our research [1].

Existing Method

Historically, tackling the challenge of setup time reduction has been approached through two main avenues. The initial strategy focused on refining operator skills to execute setup operations more efficiently, but this method ultimately yielded limited results. A second approach involved consolidating production for multiple small orders to distribute setup times across larger batches. However, this tactic often led to issues like overproduction and surplus inventory, as companies had to maintain larger stockpiles to accommodate extended production cycles. To address the costs associated with excess inventory and material handling, a third strategy emerged: the economic lot size approach. This method involved producing at an optimal lot size, determined through a balance between changeover and inventory carrying expenses. However, while these strategies provided some relief, they fell short of delivering comprehensive solutions to the setup time challenge. In contrast, the Single-Minute Exchange of Die (SMED) technique has emerged as a highly effective solution for significantly reducing setup times. By employing SMED principles, companies can streamline changeover processes, leading to notable improvements in operational efficiency and resource utilization. Unlike previous approaches, SMED focuses on identifying and eliminating non-essential tasks, optimizing tooling and equipment, and standardizing procedures to expedite setup activities. As a result, SMED has become a cornerstone strategy for manufacturers seeking to enhance agility, reduce lead times, and remain competitive in today's dynamic market landscape.

Single Minute Exchange of Die (SMED) Approach

The origins of SMED technique can be dated back to 1950, when Shigeo Shingo [6], then management consultant at the Japan Management Association, was asked to eliminate bottlenecks created by three large body-molding presses at Toyo Kogyo’s Mazda plant in Hiroshima (JMAC). During this survey Shingo had the first of a series of breakthroughs that would later become famous under the name of SMED. By observing an 800-ton press setup, Shingo realized that “there are two types of setup operation: • Internal setup – setup operations that can be performed only when the machine is stopped, such as mounting and removing dies. • External setup – setup operations that can be completed while the machine is running, such as transporting dies to or from storage” (Shingo 1989) [6]. He observed that by performing operations such as organizing and preparing the bolts externally, it was possible to reduce the setup time by 50 percent. In 1957, Shingo was investigating the operation of machining diesel engine beds at the Mitsubishi Heavy Industries shipyard in Japan. He proposed to modify the marking-off procedure so that the dimensioning and centering of the engine bed would occur in a second planar table rather than on the original table. By doing the work in advance of needs, all that was left to be done when the changeover occurred was to swap the new table with the previous one. This measure increased productivity of the planning operation by 40 percent and represented the first successful attempt to convert an internal setup operation to external. The insights gained by Shingo up to that moment were consolidated thirteen years later at Toyota Motor’s Honsha plant. Based on Shingo’s suggestions and the application of the principles of distinguishing internal and external setup operations, converting internal to external, and improving operations in both categories, Toyota was able to reduce their 1000-ton Scheoler press setup time from four-hour to three minutes. Expecting to find that any setup could be performed in less than ten minutes and having the methodology first been tested in press shop floors, Shingo named his concept “single-minute exchange of dies” or SMED (Shingo 1989) [2]. Kamal et al. (2024) a modified model was proposed as a solution, aiming to reduce waiting times by 12 %, enhance productivity by 6%, and simultaneously increase overall profitability to effectively cope with the rising demand during all the seasons. This research embodies a comprehensive effort to not only pinpoint operational inefficiencies but also to propose viable solutions that align with the industry's evolving demands. By leveraging modern simulation tools and statistical analysis, the study endeavors to contribute to the optimization of production lines, ensuring they remain adaptive and responsive in the face of increasing productivity requirements [2,16]. Hasan et. al (2014) and Iqtiar et. al. (2024) describes the productivity improvement system by using various industrial engineering tools such as 5S, Kaizen, Lean and set-up time reduction from which we have taken some significant knowledge for implementing our research [14,15].

Problem Statement:

In manufacturing operations, a process is a series of activities or procedures through which raw materials or pre-machined parts/components are transformed into finished products. To enhance production efficiency, companies often undertake process capability studies for new or modified production processes. These studies aim to optimize production performance by evaluating total variability and ensuring process stability. However, in the pursuit of process improvement, it becomes essential to compare the output of a stable process with defined specifications to assess alignment. This comparison helps evaluate how well the process meets the specified requirements. The objective of this study is to investigate the relationship between the implementation of Single-Minute Exchange of Die (SMED) techniques and equipment-to-apparatus design. Principal Component Analysis (PCA) is utilized to analyze both operator-related and process-related factors, providing insights into the functional parameters of the product. Through this approach, the process capability study serves as a valuable tool for measuring and understanding the functional aspects of the product. The central problem addressed by this study is to determine how SMED implementation impacts equipment-to-apparatus design and influences the overall process capability. By examining the relationship between these variables, the study aims to identify opportunities for enhancing production efficiency and product quality within manufacturing operations.

Methodology

Shigeo Shingo built the foundations for SMED implementation. He recognizes eight techniques for implementing SMED (Shingo 1985) [3]:

a. Distinguish between internal and external setup procedures.
b. Transform internal setup into external setup processes.
c. Focus on standardizing function rather than form.
d. Implement functional clamps or remove fasteners entirely.
e. Incorporate intermediate jigs into the workflow.
f. Introduce parallel operations for increased efficiency.
g. Remove the need for adjustments wherever possible.
h. Integrate mechanization into the system.

He also suggests that these techniques be implemented in a progressive, three stage approach (Figure 1).

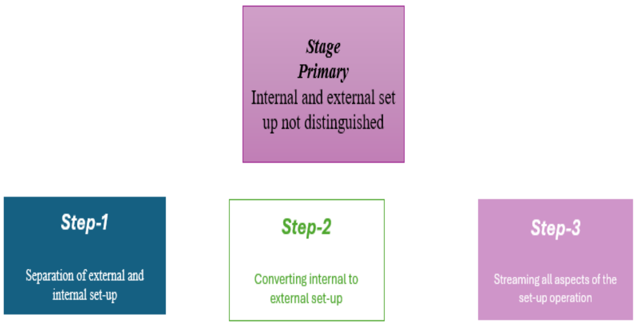

Figure 1: Theoretical steps and Procedure practices

Stage 1: To kickstart the process of minimizing setup duration, the first step entails recognizing and distinguishing between internal and external setup tasks. As depicted in Figure 1, these tasks often blur together, being carried out by operators in a somewhat disorganized manner. Experience reveals that many tasks, which could be easily conducted externally, are frequently performed internally. For instance, preparing materials and tools for the upcoming job can be accomplished before the machine is halted, even while the previous job is ongoing. Similarly, tool and component repositioning can take place after the setup is completed and while the new job is in progress. The segregation of these tasks and their external execution, rather than internal, holds the potential to significantly reduce setup time, estimated at anywhere from 30 to 50 percent (The Productivity Press Development Team 1996) [4].

Stage 2: Reimagining internal setup tasks as external ones requires a fresh perspective, where each step is scrutinized to understand its true function and necessity. Sunny (2024) describes Geographical analysis which is very crucial stage for our location selection in this research paper that has significant factor for productivity improvement when environment changes frequently [21]. This transformation entails thorough preparation of operational conditions, standardization of functions, and the incorporation of intermediate jigs. Process optimization plays a key role in facilitating this transition [17].

Stage 3: Maximize efficiency across all setup operations, including both internal and external processes. Improvements in external setup procedures can be achieved by reviewing how parts and tools are stored and transported. The implementation of 5S practices can aid in restructuring tool storage for easier access by operators. Additionally, regularly monitoring tool conditions is crucial to minimize disruptions caused by repairs or job rescheduling. When streamlining internal setup, contemplate integrating parallel operations or removing unnecessary adjustments. In traditional setups, adjustments can consume up to half of the total setup time, presenting a significant opportunity for cost reduction (The Productivity Press Development Team 1996) [4]. Finally, before opting for mechanization, thoroughly evaluate alternative techniques to ensure the most efficient approach is chosen.

Lean Tools for Setup Reduction

In addition to SMED, the field of industrial engineering literature has introduced other tools applicable to companies seeking to minimize their process setup times. These tools have a broader applicability beyond setup time reduction and are applicable to any organization aiming to enhance its processes. Kaizen, integral to the philosophy of continuous improvement in lean manufacturing, constitutes one such tool. The term "Kaizen" is Japanese, combining "Kai" (to take apart) and "Zen" (to make good), representing a gradual approach in which lean manufacturing endeavors to enhance all business processes within an organization. Operationally, kaizen is defined as a "short-term intensive effort to dramatically improve the performance of a limited scope process" (Laraia et al. 1999) [3], employing a rapid, team-based problem-solving approach. Due to its format, kaizen is often selected by firms for implementing setup reduction initiatives. In the realm of problem-solving within lean manufacturing, standardization is a crucial principle. Tahiichi Ohno, the pioneer of the Toyota Production System, emphasized, "Where there is no standard there can be no kaizen." Standardization provides the basis for comparing pre-kaizen and post-kaizen scenarios, determining improvements and their extent. Standards are fundamental for employee training and audits. Particularly in setup reduction efforts, standardization is vital as it often involves defining new procedures for setup operations. Standardization is positioned at the end of a well-defined process, aligning with Deming's PDCA (Plan-Do-Check-Act) cycle for process improvement (Figure 2). Deming's cycle forms the basis of a scientific approach to problem-solving, asserting that improvements require a systematic identification of root causes (Plan). Effective countermeasures are then developed only after analyzing and unveiling root causes (Do). Corrective actions are initially implemented on a small scale, with results assessed by comparing new and old scenarios. A gap analysis is performed between actual and expected scenarios (Check). Only after proving effectiveness are corrective actions implemented on a large scale using new, standardized operating procedures (Act). This approach ensures that problems are addressed at their root, preventing future recurrences.

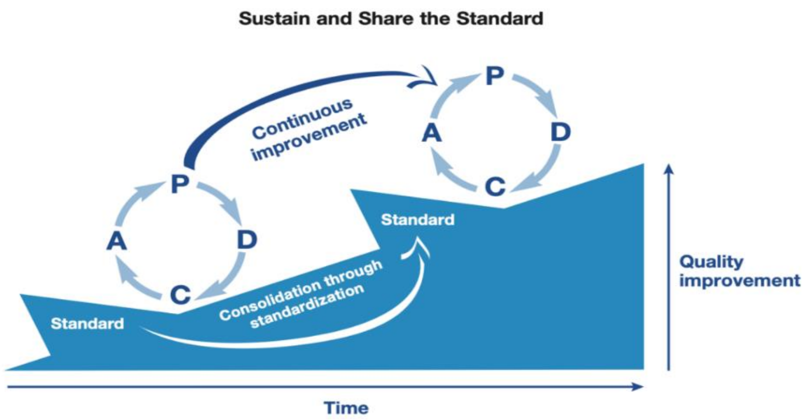

Figure 2: Standardization and PDCA [1]

Another valuable tool in the realm of lean manufacturing, frequently advantageous in setup reduction, is 5S. This operational approach is designed to establish a clean, organized, safe, and productive workplace. The term "5S" is derived from the five Japanese words representing continuous improvement: Seri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize), and Shitsuki (Sustain). 5S proves beneficial in setup reduction initiatives in several ways. The removal of dirt and dust contributes to better equipment maintenance and creates an environment where machine malfunctions are easier to detect, ultimately preventing breakdowns—a common cause of prolonged setups. Moreover, more reliable equipment reduces the likelihood of producing defective products, leading to shorter first-piece quality inspections. Safety is also enhanced through increased detection of abnormalities and hazards, while the elimination of unnecessary tools contributes to maintaining a risk-free environment. Ultimately, a cleaner workplace boosts morale, often translating into increased work productivity.

High Volume, Low Margin Manufacturing

Historically, SMED techniques have found application in sectors where "lean" methodologies are implemented to enhance profit margins, facilitate cost reductions, or prevent the outsourcing of manufacturing to low-cost labor markets. Industries characterized by high-volume production of low-margin products, such as consumer electronics, have also utilized SMED. Devices like mobile phones, MP3 players, tablet computers, and readers fall into this category. In these industries, the following aspects of SMED implementation are particularly relevant:

Separation of internal and external operations: For instance, the changing of large multi-cavity injection molding tools for cell phones, which previously took up to four hours, can now benefit from separating mold heating and fixturing operations, reducing downtime.

Conversion of internal to external processes: Processes like heating the mold to achieve uniform and proper molding temperature, which used to take several hours within the press, have been transformed into more efficient external operations. Standardization of function, not shape: Innovative mold design concepts, like plate molds, have emerged to accommodate lean manufacturing. These molds feature thin removable plates with shapes for individual plastic parts, facilitating easier movement in and out of the press for part removal.

Use of functional clamps or elimination of clamping: Lean principles have simplified clamping of molding tools onto press plates. Modern clamps designed with self-locating and floating catch bars secure molds in a few imprecise positions, departing from the rigid angle iron structures of the past.

Adoption of parallel operations: In the consumer electronics sector, where numerous parts need molding, loading inserts into mold cavities was traditionally done manually. Vision systems now enable this loading operation outside the press, with automatic verification before loading into the mold, further confirmed by intelligent agent vision systems.

Mechanization: Lean manufacturing principles have deeply influenced the plastics injection molding field. Automatic mold changers have been developed to bring high levels of automation and productivity to high-volume, small-lot manufacturing operations. These systems are particularly valuable in industries like consumer electronics, where multiple mold changes are necessary to manage inventory costs and align production schedules with the fluctuating demand cycles. Mechanized tables and robotic carts complement these automatic mold changers, providing a safe and compact configuration for various plastic molding tools.

Construction of SMED Stages

Drawing on the principles of Shigeo Shingo, the scientific approach of the PDCA process to problem-solving, and the concept of kaizen, a comprehensive method has been developed as a reference for any company engaging in setup reduction kaizen. A notable case study by Souke (1999) presented a predictive model for setup reduction, serving as a valuable reference for future applications [6]. The method outlined in this paper integrates a general setup reduction model into kaizen, acknowledging the constraints of time and resources. Before initiating a setup reduction kaizen, it is imperative to identify the need for reducing setup times. The goal should not be merely reducing setup time to an arbitrarily chosen duration; instead, it should align with a broader objective, such as addressing a capacity bottleneck or resource shortage. This focus ensures project alignment and commitment. Setup time, also known as changeover time, is defined as the duration from completing the last good part of one lot to completing the first good part in the next lot. Unlike the traditional notion that focused solely on tooling attachment and detachment, actual changeover time encompasses all activities required to prepare the machine for producing the new lot. It is crucial to include the time spent producing the first part of the new lot, often performed in manual mode with longer cycle times. Various approaches can be employed to study the setup process. Using a stopwatch provides a reasonable estimate of setup times, while being on the shop floor offers insights difficult to capture from a secondary view. Video filming, reviewed with the kaizen team, allows for a thorough analysis of each setup activity. Operators, likely members of the kaizen team, can describe their actions and reasoning, enabling group discussion. Spaghetti charts and setup observation analysis worksheets, utilizing the "FAST" categories (Foresight, Attachment, Setting, Trial runs), aid in documenting activities and times for analysis.

FIRT Categories:

F - Foresight or preparation step A - Attachment or mounting/dismounting Step S - Setting, centering, dimensioning T - Trial runs and adjustments. The significance of each category is reflected in typical percentages of total time, as shown in Table 1 (Shingo 1989) [3].

Table 1: Basic Setup Steps before SMED Improvements

Step	Percentage of Setup Time
Preparatory Measures, Post-process Adjustments, Verification of Materials and Tools	35%
Attaching and Detaching Blades, Tools, and Components	10%
Dimensions, Configurations, and Adjustments	10%
Testing Iterations and Fine-Tuning	45%

Idea Prioritization and Idea Assessment Matrix

The concept of an assessment matrix is rooted in the understanding that decision-making processes involve multiple factors, each carrying varying degrees of importance. Without a structured approach to evaluate these factors objectively, assessing competing elements can be challenging. A weighted matrix provides a systematic method for identifying and assessing these factors, leading to more informed and rational decision-making. In the context of setup reduction assessment, the aim is not necessarily to identify a single, optimal solution, but rather to systematically evaluate the effectiveness of each idea in improving setup operations. To facilitate this process, five specific criteria have been defined and are detailed in Table 2. This approach ensures a thorough and nuanced evaluation, ultimately contributing to a more comprehensive and reasoned approach to improving setup operations.

Table 2: List of Factors for Idea Assessment Matrix

Measure	Dimension of Evaluation
Agility	Can the concept be practically put into action?
Effect	What extent of influence will the concept have on reducing setup time?
Feasibility	How straightforward is the implementation of the concept?
Security	What level of safety does the suggested approach ensure?
Cost	What is the cost associated with implementing the suggested concept?

To account for the relative importance of each criterion, weights from 0 to 10 (with a 5-point interval) are assigned. It is important to note that weights should be assigned by management, as they come to reflect the strategic outlook of the company in determining, for instance, whether priority should be given to cost rather than ease of implementation. The team ranks each idea with a value ranging from 0 to 5 on each decisional criterion, and a total score is calculated as follows:

$$\text{Idea Total Score} = \Sigma \text{ criteria (weight * score)} \quad (1)$$

Ideas with higher scores should be implemented first, as they represent the most feasible, fastest, and least costly consuming solutions.

Idea Implementation

A preliminary Standard Operating Procedure (SOP) is established based on initial improvement suggestions, aiming to validate the efficacy of the new procedure as additional methods for setup reduction are identified and put into practice. A comprehensive plan for the kaizen follow-up is developed, encompassing the following key components:

Training: Recognizing the pivotal role of education in the success of setup reduction initiatives, operators are provided with training on quick changeover techniques. It is crucial to ensure that operators understand the rationale behind scrutinizing setup procedures to avoid misconceptions that may lead to nervousness and deviations from standard practices. Communication Plan: Effective communication is essential for ensuring that all employees directly or indirectly impacted by the changes are informed and aware of the new procedures. This is particularly critical for the first setup reduction project, as it signals leadership support and underscores the necessity for change. Implementation Plan: An actionable plan is devised to connect selected ideas with the necessary steps for implementation. This plan outlines the responsibilities (who), tasks (what), timelines (when), locations (where), and methods (how) for executing the proposed solutions. Regular reviews and updates of the plan are conducted, with weekly meetings scheduled to monitor progress, address unforeseen challenges, and track results against initial goals. Evaluation and Corrective Measures: Upon completion of the follow-up phase, a meeting is convened to assess the effectiveness of the actions taken and identify any remaining issues requiring corrective measures. This allows the team to reflect on the outcomes achieved, determine areas for improvement, and implement further adjustments as needed. By employing a systematic approach encompassing training, communication, implementation planning, and continuous evaluation, the organization can effectively drive setup reduction efforts and foster a culture of continuous improvement and operational excellence.

Idea Validation, Adjustments and Standardization

As per PDCA methodology, improvement of setup operations is an ongoing process made of continuous little adjustments rather than a one-shot event. By performing one or more turns in the PDCA cycle, one can improve its plan and/or develop contingency plans to address unforeseen circumstances. As implementation efforts take place, the SOP is periodically reviewed until the final standard work is eventually defined. It is important that the standard work instructions be documented and made visible to all in the working area. The team must develop and complete training for all operators who will be performing the new setup to make them familiar with the new procedure. Enforcement of new measures is also important to make the new procedure become a habit. Audit sessions should be scheduled to periodically analyze results and keep track of improvements.

Implementation

The method explained above was applied to a mid- sized manufacturing facility that produces track roller bearing systems for use in military and commercial aviation industry. In particular, the project focused on reducing setup times in a CNC turning center dedicated to outer races production. The outer race production process takes place in two distinct sequences. During the first sequence, the part is held by the main spindle on the left side of the turret while tools shape the OD (outer diameter) and ID (inner diameter). The part is then cut off from the original bar of material and work shift takes place, where a secondary spindle (sub-spindle) moves close to first spindle and the part is transferred on the right side of the turret. The problem in the track roller production process was that of long lead times. 20 days are usually required to fulfill the customer's order whereas the lead time demanded by customer is five days for the same process. Also, due to inner and outer different cycle times, outer production was falling behind schedule, causing excess inventory of inner parts, which were waiting for their pairs before they could eventually be moved forward in the process as an assemble kit. Reducing setup would allow the company to avoid the bottleneck problem at the CNC turning center, while shortening the overall production lead time and lowering the amount of work in process inventory. The setup reduction effort was carried out with a kaizen format. A team was assembled, which was comprised of the following: two machine operators, one kaizen expert, one engineer expertise with injection mold.

The first part of the kaizen was dedicated to the as-is analysis. A setup process was videotaped, which allowed the team members to analyze the steps performed by the operator, his movements, and the time for each step. Also, a spaghetti chart was drawn, where distances travelled by the operator were recorded. With the help of the machine operator, activities were listed and the "setup observation analysis worksheet" compiled (Table 3). For each activity, time, and setup activity (defined as either internal or external) were recorded. Also, activities were classified into the "FIRT" categories. As shown in the sheet, in the as-is state, most tasks were performed internally, adding up to a total setup time of 1 hour and 25 minutes. The second part of the kaizen was spent brainstorming ideas for setup process reduction. Activities were classified as internal or external, and those identified as external were taken out from the setup worksheet to create a separate kitting procedure. Molding" refers to the practice of assembling and positioning all required tooling near the machine prior to initiating the setup process. This is executed while the machine continues to operate on the previous part. The subsequent tasks were outsourced, resulting in a collective time reduction of 16 minutes:

- Acquire shop order and confirm stock dimensions
- Generate a hard copy of the program from the computer
- Procure new tools and equipment (such as collets, jaws, spindle liners, inserts, boring bars, tool holders, and drills)
- Arrange gage blocks, plugs, etc., for setup
- Store new tools and equipment in their designated locations.

To enhance internal processes, a proposal was made to reengineer background edits, suggesting loading the CNC program while the machine runs the previous part, rather than during setup. Various ideas for improving the setup process were brainstormed and linked to corresponding steps in the setup observation analysis worksheet. These ideas were evaluated by the team using the idea assessment matrix, with feasibility, impact, and safety weighted more heavily than cost and ease of implementation. A standard setup procedure was established, and a dry run was conducted to test the new standards. A total of 24 minutes were saved by moving some activities from internal to external processes (10 minutes) and modifying work shifts (7 minutes). The proposed ideas were reviewed and integrated with new suggestions arising during a second setup observation. Many ideas focused on tooling and area reorganization, leading to a scheduled 5S session. These activities facilitated a more efficient equipment reordering and storage process at the point of use. A follow-up audit session conducted 40 days after kaizen completion revealed significant improvements, particularly in externalizing and changing out ID operations (17 minutes savings) and reengineering work shifts (7 minutes savings). Additionally, a post-kaizen video demonstrated a further 10-minute reduction in setup time (reduced to 50 minutes), indicating potential for improvement with machinist training in standard work. Training in presetting operations could further reduce setup time, particularly in jaw attachment operations, which accounted for a quarter of the total setup time. Subsequent post-kaizen videos confirmed the need for improvement in this area, with significant time still spent on jaw attachment and adjustments. Despite progress, the final shot revealed a 50-minute setup, highlighting ongoing challenges in jaw attachment and work shift setting. The research demonstrates a decrease in changeover time ranging from 50% to 64% following the implementation of SMED, as measured by two primary metrics: throughput time and time to achieve peak production. Additionally, the successful implementation relies on utilizing the RACI matrix to allocate responsibilities effectively and integrate SMED with the fundamental production flow both prior to and after its application [20].

Table 3: Setup Study Evaluation Database

Engine S/L	Time		Working Procedure	Task Completion	Ref to the work
	Cumulate.	Task			
1	0:01:02	0:01:02	Start Database Loading	0:01:00	2
2	0:03:34	0:01:34	Mold set-up	0:01:32	
3	0:03:05	0:00:27	Finf new spindle	0:00:27	1
4	0:04:01	0:01:00	Insert mold on Holder	0:01:00	9
5	0:06:21	0:02:20	setting the mold into bar	0:02:20	9
6	0:12:40	0:06:19	Change cut off/OD Inserts	0:06:19	11
7	0:21:05	0:07:25	taking out bars on the new side	0:08:25	1
8	0:27:36	0:06:31	sensor off with the interface	0:06:31	3
9	0:28:22	0:00:46	hand tools taken away	0:00:46	10
10	0:29:50	0:01:28	collect data after mold change	0:01:28	3
11	0:32:05	0:02:15	insert new spindle to the bars	0:01:55	1
12	0:38:05	0:06:00	bar set-up on new mold	0:07:00	1
13	0:43:34	0:05:29	Load the stock and set the height of the bar feed	0:05:29	1
14	0:43:34	0:02:25	ID setting for insert bar	0:01:38	4
15	0:47:50	0:01:51	primary schedule to zero position	0:01:49	
16	0:52:32	0:04:42	Conduct a trial or practice operation of the primary spindle,	0:04:42	
17	1:01:00	0:07:28	Replace the jaws on the secondary spindle.	0:07:32	7
18	1:05:09	0:04:09	sliding bars modify and check	0:04:09	7
19	1:08:36	0:03:27	Adjust sub-spindle cutoff length to align with the main spindle.	0:03:31	
20	1:13:00	0:04:24	Call up tools for sub spindle Zero	0:03:24	
21	1:18:23	0:05:23	Conduct a practice execution using G/M code	0:04:23	
Totals				1:15:20	

When Shigeo Shingo introduced the Single-Minute Exchange of Die (SMED) methodology, he pioneered a shift from individual problem-solving to a team-based approach in kaizen. Unlike the initial scenario where Shingo worked independently, kaizen involves the entire team in generating ideas to enhance setup operations. The process begins with a thorough evaluation of the current state, followed by the implementation of SMED. Initially, the team distinguishes setup activities into internal and external components. Activities mistakenly considered internal are transitioned to the external category. Subsequently, the team reviews the entire setup sequence to identify internal steps that can be converted into external ones. A comprehensive brainstorming session ensues, aimed at proposing solutions to streamline both internal and external operations. The ultimate objective is to establish a "standard operating procedure" (SOP) for setup activities. It is crucial to emphasize that standardization is the linchpin for ensuring sustained and effective improvements over time.

Activity Categories			
F. Foresight 12% (30 min)	I. Insert 41% (25 min)	R. Relocation setting 27% (15 min)	T. Trial Runs & Adjustments 20% (10 min)

Table 4: Idea Assessment Matrix

	Weight	8	6	4	8	4	Total Score
	Operation Idea	Agility	Effect	Easiness	Human Safety	Cost factor	
1	Backdrop Modification	5	1	5	5	5	126
2	Engineer needs as expert	4	6	4	4	2	124
3	while the machine is in operation,utility cart for temporarily setting aside tools	3	2	4	4	3	96
4	liner mark should clear	4	3	6	5	7	142
6	Start up procedure should fully automatic	5	2	6	6	4	140
7	Jaws specified by size/ID range.	6	1	4	4	5	122
8	Prioritize external machinery during setup.				1	3	20
9	tool holders require improved organization, preferably vertically with clear, easily readable labels		3	2		1	30
10	Boring bar tool holder for tabletop use.	5	4	5	5	5	144
11	Collet holder rack	4	4	4	5	4	128

Conclusions

This study focuses on implementing the Single Minute Exchange of Die (SMED) methodology to reduce setup time within a manufacturing company. The findings indicate a significant reduction in setup time, with the potential to decrease the initial 2 hours and 20 minutes to just 80 minutes. Additionally, through adjustments in the jaw attachment device and optimizing work shift arrangements, an additional 17-minute reduction in setup time was achieved. The successful implementation of lean manufacturing requires active involvement from all departments within the company, as well as enforcement of standard work practices to overcome resistance to change. Regular monitoring, as part of kaizen follow-up practices, motivates machinists to adhere to new procedures and adapt to changes. Senior management plays a crucial role in driving lean initiatives and fostering a culture of change management and collaborative problem-solving. Throughout the study, it became apparent that functions such as jaw attachment and CNC program updates significantly impact the company's kaizen goals, highlighting the importance of labeling jaws and updating CNC programs. To ensure consistent application of new procedures, management should develop a comprehensive training plan for operators and implement enforcement measures. By championing lean initiatives and providing necessary support, senior management can facilitate a smooth transition towards improved operational efficiency and a culture of continuous improvement within the organization.

Future Works

Conducting in-depth case studies across a broader spectrum of electronics manufacturing facilities could provide valuable insights into the variability of setup processes and the effectiveness of SMED implementation in diverse operational contexts. By examining different manufacturing environments, including high-volume production lines and specialized electronic component assembly operations, researchers can identify industry-specific challenges and opportunities for optimizing setup procedures and the integration of advanced technologies such as artificial intelligence (AI), machine learning, and robotics presents promising avenues for automating setup tasks and streamlining changeover processes in the electronics industry. Investigating how these technologies can complement SMED methodologies to further reduce setup times while maintaining product quality and operational flexibility would be an intriguing area for future exploration. Furthermore, research efforts could focus on developing comprehensive training programs and educational materials to build capabilities and empower personnel at all levels of the organization to effectively implement SMED techniques. Providing hands-on training, workshops, and certification programs tailored to the specific needs of electronics manufacturing professionals would facilitate knowledge transfer and skill development in setup time optimization.

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