



Manufacturing Systems & Simulations

APPLYING LEAN TECHNIQUES – TME TO TEST

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Abstract

This paper investigates various aspects of waste within the workplace, specifically within the Tata Steel Spectroscopy Lab. It discusses strategies for reducing and eliminating waste, as well as the impact of waste on the Time to Test process. Furthermore, the paper analyses value creation from the customer's perspective, evaluates current processes, and proposes lean methodologies for process optimization. The study concludes with recommendations for addressing challenges related to Time to Test within the laboratory.

Contents

Abstract	1
Table of Figures.....	3
Introduction	4
1 Process Mapping	5
2 Types of Waste at the Workplace.....	6
3 Transportation.....	7
3.1 Transportation Improvements	7
4 Inventory.....	8
4.1 Miller Tips.....	8
4.2 Lamson Carriers	8
4.3 Inventory Improvements	8
5 Motion	11
5.1 Searching For Delivered Samples	11
5.2 Locating Maintenance Spares.....	11
5.3 Motion Improvements	11
6 Waiting	14
6.1 Maintenance Of Equipment	14
6.2 Waiting Improvements	14
7 Over processing.....	16
7.1 Overprocessing Improvements.....	16
8 Defects	18
8.1 Defect Improvements.....	18
9 Customer Satisfaction	20
10 Quantifying Wastes.....	22
11 Conclusion	23
References	24

Table of Figures

Figure 1 - Process Map from Arena Software	5
Figure 2 - Waste overview of Timwoods	6
Figure 3 - Miller Head with new tips.....	9
Figure 4 - Sample Preparation Standard	9
Figure 5 - Outdated Visual Light System	12
Figure 6 - 5s Lean Workplace	12
Figure 7 - Expected 5s Robot Standard	13
Figure 8 - Live System for Individual Casts	15
Figure 9 - BOS Plant Daily Charging Schedule.....	15
Figure 10 - Robot	17
Figure 11 - Under Weight Steel Sample	19
Figure 12 - Poorly Prepared Steel Sample.....	19
Figure 13 - Miller Tool Count.....	19

Introduction

The Time to Test is of utmost importance in the analysis of steel samples received from the Basic Oxygen Steelmaking (BOS) plant. At the BOS plant, steel is modified to meet desired grades by adding specific elements to the molten mixture using a lance. Given that these modifications are made in real-time, there is a critical need for rapid analysis turnaround.

However, achieving satisfactory Time to Test for these specific samples presents significant challenges, exposing several inefficiencies within the process. These challenges typically stem from various factors, including human error, equipment failures, and inadequate planning (Nejad, et al., 2022).

By systematically addressing the causes of waste and implementing necessary improvements, this study aims to enhance the turnaround time of steel samples. Through a combination of empirical analysis, stakeholder engagement, and continuous improvement efforts, this research seeks to deepen our understanding of various inefficiencies within the process. Ultimately, it aims to improve performance and sustainability in industrial operations.

1 Process Mapping

The process of steel analysis in the Spectroscopy lab involves several key steps, outlined as follows as shown in figure 1. The initial step involves the delivery of samples. These samples are typically transported from the BOS plant to the laboratory via Lamson lines. There are ten Lamson lines, each designated for different sections of the BOS plant, beginning with the vessels, followed by the treatment stations, and concluding with the casters.

The second step is collection of Steel Samples by Lab Personnel. Upon arrival at the lab, a generic alarm sounds, accompanied by a red light flashing on a dashboard. Technicians then retrieve the sample safely from the Lamson line.

The third step involves the preparation of the steel sample prior to its entry into the analysis system. Samples often have stems attached, which need to be removed either using the Hertzog Cutter or manually by finishing the sample with a grinding disc mill. Technicians then weigh the sample to ensure it meets the required specifications before placing it into the entry slot for collection by the robots. Additionally, the sample's identification is recorded in the Samtracs program on a computer.

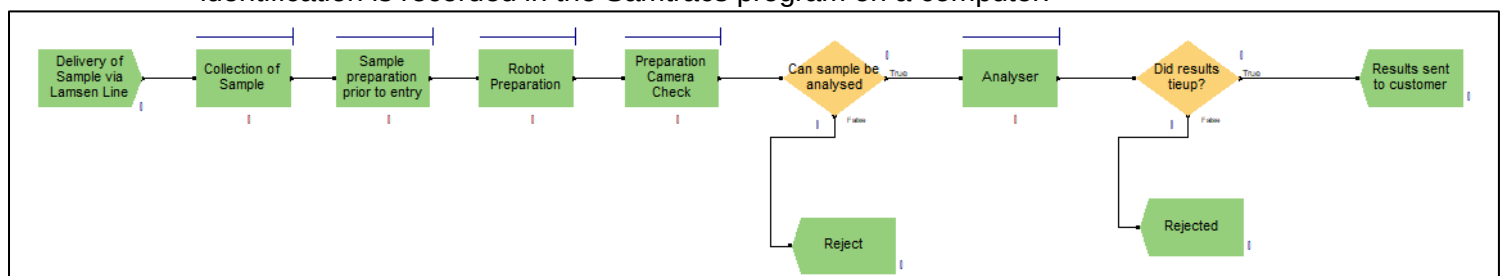


Figure 1 - Process Map from Arena Software

The penultimate step is the robot preparation of the steel sample. The robot detects when a sample has been entered and proceeds to collect it, placing it into the miller to ensure a clean, flat surface for analysis. Following the milling process, the robot retrieves the sample and positions it into the Optical Emission Spectrometer (OES). The OES then performs up to four spark analyses to determine the chemical composition of the sample. After the spark analysis, the robot retrieves the sample from the OES, passes it through a printer to print the identification number for storage and audit purposes, and finally deposits it into the completed tray. The final step is the storage of steel samples. Technicians retrieve the samples and store them in seed packets, each labelled with the specific cast number. These samples are retained for several months to address any potential customer complaints or recalls (Weiss, et al., 2022).

2 Types of Waste at the Workplace

There are eight different wastes that are evident in the workplace, these eight different wastes can be remembered by the acronym 'TIMWOODS', which is summarised in figure 2.

'TIMWOODS' is an acronym used to identify waste within the Lean methodology. There are 8 forms of waste, which are represented by TIMWOODS, this acronym stands for transport, inventory, motion, waiting, over production, over processing, defects, and skills utilisation (Marion & Power, 2023).



Figure 2 - Waste overview of Timwoods, (NHS, 2022)

These eight forms of waste are present at various stages throughout Tata Steel, Port Talbot. This paper is focused on improving the Time to Test of steel samples from the BOS plant and eliminating waste from the process.

3 Transportation

Throughout the process, transportation is only required at the beginning when technicians walk to the Lamson lines to obtain the sample. However, the Lamson lines, Hertzog cutter, and sample entry points are situated in different locations within the lab, causing an additional time delay in the analysis process (Pierce, et al., 2023). Although the walking distance is not significant, the layout of the lab could have been designed more efficiently during the assembly of robots, millers, etc.

3.1 Transportation Improvements

Transportation waste within the Spectroscopy lab is challenging to eliminate due to the existing Lamson lines infrastructure. However, if new equipment is installed or a new lab is constructed, it is crucial to plan the layout in advance to achieve maximum efficiency.

4 Inventory

Inventory items, such as the maintenance of Miller tips and Lamson carriers, can contribute to an increased Time to Test.

4.1 Miller Tips

There are two millers in the laboratory, each equipped with a rotary milling spindle that contains five milling tips. Changing these tips renders the miller temporarily unusable, leading to samples being parked by the robot and significantly increasing the Time to Test.

4.2 Lamson Carriers

Lamson line carriers may become obstructed in the lines due to factors such as general wear and tear, damage to the line, or adverse weather conditions. These carriers must adhere to specific size requirements, which are measured using a tool to ensure their suitability for use.

4.3 Inventory Improvements

Improving test turnaround time by addressing inventory waste can be achieved with minimal expenditure and effort. The laboratory currently operates two millers, each equipped with a spindle containing five tips, as shown in figure 3. The criteria for changing these tips are currently vague and rely on subjective judgments, such as visual inspection of rejected samples or the experienced staff's ability to discern wear based on the sound during milling.

To enhance efficiency in the changeover of miller tips, a wear count system could be implemented and integrated with Samtracs. This system would track the number of samples processed by each set of tips before requiring replacement. A maximum wear count threshold, based on empirical data and technician experience, would be established. Samtracs would then notify technicians when this threshold is reached, prompting timely maintenance and thereby improving overall efficiency (Bicheno & Holweg, 2023).

This system offers a standardised and objective method for determining when tips need replacement, thereby reducing reliance on subjective judgments.

Another improvement involved procuring spare miller spindles. The spectroscopy lab acquired two additional miller spindles, each pre-fitted with five new tips. These

spindles are stored adjacent to the machines to facilitate a quick changeover process. When tips reach their wear limit, technicians can promptly replace the entire spindle rather than individually changing each tip by following the procedure in figure 4. This approach minimises miller downtime, as the removed spindles can be serviced and have their tips replaced offline. Consequently, sample analysis is not delayed by maintenance activities.



Figure 4 - Miller Head with new tips



Figure 3 - Sample Preparation Standard

Addressing issues with the Lamson line can be challenging, as they often necessitate external maintenance. However, discussions with Quirepace (Lamson Engineers) have underscored the importance of daily inspections of the carriers. These carriers, which must adhere to specific size requirements, can become worn from repeated use, potentially causing them to become stuck in the line. To mitigate these issues, visual aids and reminders have been implemented. Posters and visual aids have been installed in key areas of the laboratory to remind staff to regularly check the condition of the carriers. These visual cues are designed to reinforce the importance of daily inspections and encourage technicians to remain vigilant.

Process confirmations were introduced at the start of each shift to encourage technicians to inspect each carrier at the beginning of their shift, ensuring it is in suitable condition for use. This routine check is documented to maintain consistency and accountability (Lalic, et al., 2020). Additionally, checklists have been made available for technicians to use during these inspections, covering key aspects such

as carrier size, wear, and overall condition. This structured approach ensures that all critical aspects of the carrier's condition are thoroughly reviewed, and no detail is overlooked.

A detailed set of criteria defining what constitutes a "suitable" carrier, including specific measurements and wear indicators, was communicated to each staff member. This standardization aims to assist technicians in making accurate assessments during their inspections. Additionally, training sessions were conducted to ensure that technicians understood how to properly inspect the carriers and recognize signs of wear. These measures are designed to enhance the effectiveness of the daily inspections.

5 Motion

Motion waste in a process involves unnecessary physical movement that does not contribute value to the product or service. In the Spectroscopy Lab, this waste manifests in several ways.

5.1 Searching For Delivered Samples

When a sample arrives at the lab, a generic alarm sounds, and a red light flashes on the dashboard. However, if the light does not specify the particular line where the sample is located, technicians are required to walk to each line to locate the sample. This unnecessary movement results in wasted time and effort.

5.2 Locating Maintenance Spares

During equipment maintenance, technicians often lose valuable time searching for spare parts. These items are stored in a cupboard or toolbox without proper organization or labelling, making it difficult and time-consuming to locate the required parts.

5.3 Motion Improvements

Improving the time to test can be achieved by reducing motion waste, which currently arises from uncertainty regarding the location of inventory or samples. A significant source of this uncertainty is the occasional malfunction of the red light intended to indicate the arrival of a sample, where figure 5 shows the current indication system. To address this issue, enhancements to the red-light system were considered necessary to ensure reliable signalling of sample arrivals.

One proposed solution was a system update that included a larger display unit to provide clearer and more visible notifications of sample arrivals. Although many technicians found this idea desirable, it was not financially feasible. An alternative suggestion was to modify the generic alarm that sounds with each sample delivery to emit different alarms based on the specific Lamson location of the sample (Mulugeta, 2021). This would reduce the time wasted locating samples by providing more precise auditory cues. However, this improvement was also not approved due to financial constraints.

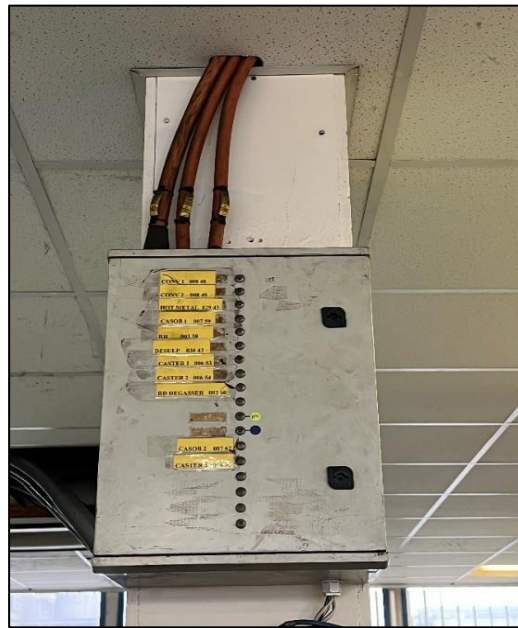


Figure 5 - Outdated Visual Light System

The organization of critical spares and parts within the Spectroscopy Lab is currently inefficient. To address this issue and enhance overall efficiency, the 5S methodology was implemented.



Figure 6 - 5s Lean Workplace, (Starbank, 2019)

5S is a crucial tool employed to enhance efficiency at Tata Steel's Spectroscopy Lab, where an overview is seen in figure 6. The first step, Sort, involves disposing of unnecessary parts, used consumables, and waste such as packaging and boxes. The second step, Set in Order, has been improved through the implementation of a kanban

system. This system ensures that consumables, standards, and personal protective equipment (PPE) are clearly labelled and easily identifiable (Gupta, 2022).

Maintaining good housekeeping standards at Tata Steel is essential for both improving testing times and ensuring safety. The Shine step has become ingrained in the culture, with most of the workforce ensuring that their workstations are left in an acceptable condition. Standardise is achieved when the first three S's are consistently upheld. Visual management tools have been introduced in various areas to clearly display the required standards for maintaining workspaces (Monnanyana & Gupta, 2021).

The 5S process is sustained through regular process confirmations conducted throughout the week across different areas, where in figure 7, an example is shown. This practice ensures that all personnel and shifts adhere to the established standards.

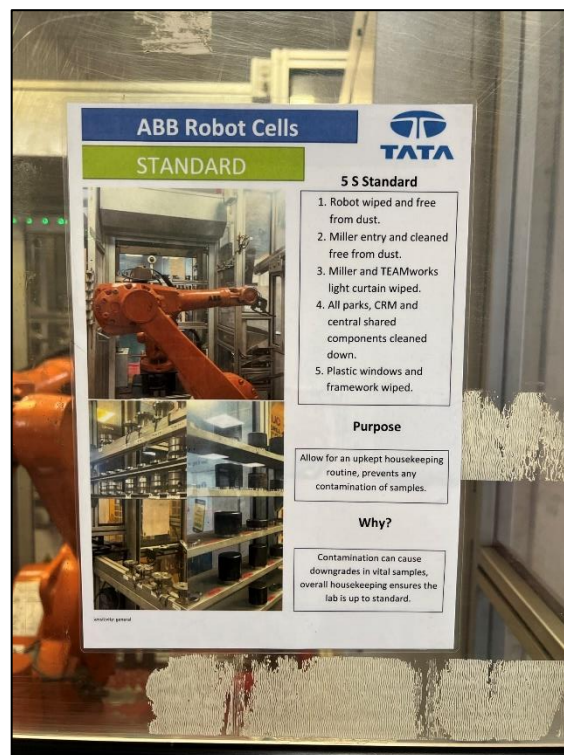


Figure 7 - Expected 5s Robot Standard

6 Waiting

Waiting waste refers to the downtime of people, materials, or equipment when they are not actively contributing to the production process (Shahriar, et al., 2022). In the Spectroscopy Lab, this type of waste significantly impacts turnaround time.

6.1 Maintenance Of Equipment

The changing of miller tips, running additional standards, and periods when one of the Optical Emission Spectroscopy (OES) machines is out of use can significantly impact the turnaround time for each sample.

6.2 Waiting Improvements

Waiting waste often arises from the maintenance of critical equipment, leading to significant downtime. One of the Optical Emission Spectroscopy (OES) machines is frequently out of use due to maintenance, which impacts turnaround time as the system becomes overloaded. During such instances, robots are forced to park samples, further delaying testing.

Although maintenance is essential, there is potential for improvement to mitigate its impact on the lab's turnaround time for each sample. Enhancements have been made in planning and communication to address these issues. Improved planning ensures that maintenance activities are scheduled in advance to minimise disruptions to testing schedules, where in figure 9 the schedule is shown. Additionally, clear communication between day staff, external contractors, and shift teams helps coordinate maintenance activities more effectively (Al-Zuheri, et al., 2021). The visibility of the BOS plant schedule has also been increased, facilitating better alignment of maintenance activities with periods of minimal workload.



7 Over processing

Excess processing is a sign of a poorly designed process. This could be related to management or administrative issues such as lack of communication, duplication of data, overlapping areas of authority and human error. Excess processing can occur during the testing process of steel samples, primarily due to human error (Stern, 2019).

When steel samples are delivered from the BOS plant, they are accompanied by a cast number. Lab technicians enter this information exactly as it appears on the ticket. However, mislabelling or misinterpretation of the cast number can occur, leading to delays as the sample may need to be retested. Additionally, if the robot drops the sample from its grippers, the sample will need to be reprocessed, as the milled surface may have come into contact with impurities, potentially affecting the analysis.

7.1 Overprocessing Improvements

Overprocessing of samples is a daily challenge in the Spectroscopy Lab, with a significant portion of this issue attributed to problems with robot grippers and worn tips on miller spindles, where the robot is shown in figure 10. To address these issues and reduce overprocessing, maintenance is carried out on the robot grippers to prevent misalignment and out-of-sync actions. Prompt realignment of the grippers is essential to avoid issues such as dropping samples during rotation (Klein, et al., 2021). Failure to realign the grippers can lead to dropped samples, which necessitates technicians entering the guarding area to retrieve them, resulting in additional time wastage and increased safety risks.

To mitigate these problems, a daily inspection protocol for robot grippers has been introduced at the start of each shift as part of the preflight checks. Lab personnel are required to inspect the grippers to ensure they are in proper working condition and safe to use. Any issues identified during the inspection should be addressed immediately to prevent operational disruptions.



Figure 10 – Example of a robot in operation

8 Defects

Defects have a detrimental impact on time, money, resources, and customer satisfaction. These defects include samples that are underweight or hollow, poor surface preparation due to issues with the Miller tips, and samples that are out of specification due to modifications made in the BOS plant, which ultimately results in their rejection. Examples of these can be found in figures 11 and 12.

In addition, a sample rejection may occur if, despite performing the maximum of four sparks on the Optical Emission Spectrometer (OES), no chemical element tie-up is achieved. This situation could arise from a combination of the previously mentioned issues—underweight or hollow samples, poor surface preparation, and out-of-specification samples. As a result, the sample must be reprocessed from the entry stage into the robot, leading to significant time wastage (Rajab, et al., 2022).

8.1 Defect Improvements

Defects or rejections of samples significantly increase turnaround time in the Spectroscopy Lab. To address this issue, visual aids and reminders have been placed throughout the lab to prompt technicians to visually inspect and weigh samples before they are entered into the system. These measures aim to ensure that technicians consistently follow proper procedures for sample inspection, thereby minimizing the risk of rejection due to avoidable errors.

The visual aids also promote a prompt response in the event of a rejected sample, reminding technicians to contact the originating area to ensure timely communication and prevent further delays (Megawati, et al., 2020). Since rejections are closely related to the surface preparation of samples, monitoring the wear of miller tips is critical, as shown in figure 13. By replacing tips before they become excessively worn, technicians can maintain a high-quality surface finish, thereby reducing the risk of sample rejection.



Figure 11 - Poorly Prepared Steel Sample



Figure 12 - Under Weight Steel Sample

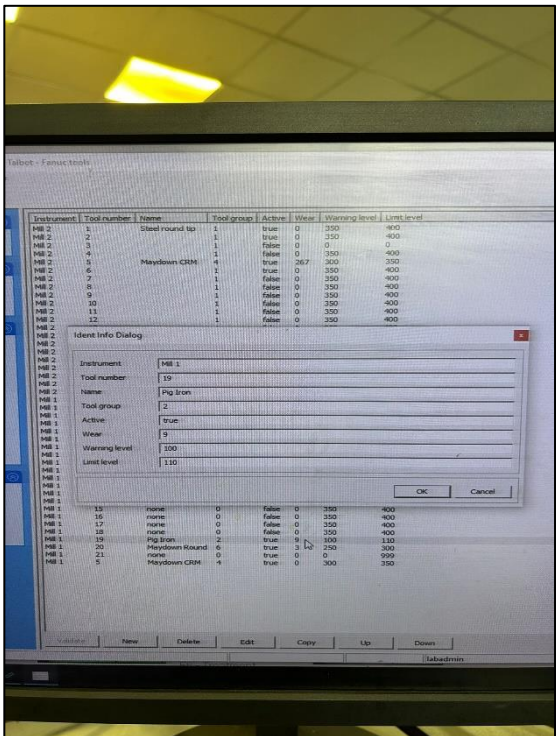


Figure 13 - Miller Tool Count

9 Customer Satisfaction

Tata Steel's laboratories are crucial for maintaining the high quality of products by providing essential analytical services, primarily to internal customers. The Spectroscopy Lab, in particular, supports the Basic Oxygen Steelmaking (BOS) plant, a pivotal element in the steel production process.

Within the BOS plant, various stations are strategically positioned. Molten iron is initially transported from the Blast Furnaces to the BOS plant via a torpedo. At the plant, the iron is transferred into a ladle, marking the commencement of the Basic Oxygen Steelmaking process. The laboratories receive samples from each specific cast as it progresses through different treatment stations, ultimately leading to the steel being cast into slabs.

The turnaround time for each sample is critically important in the BOS process, which operates at a high speed. Each treatment station depends on the timely analysis of samples from previous stages before proceeding with additional modifications. Delays in reporting can have significant cost implications and disrupt business plans (Deshmukh, et al., 2022).

The importance of timely analysis in the BOS process is closely tied to operational efficiency. The BOS process demands rapid and accurate analysis from the Spectroscopy Lab to ensure a seamless flow of operations. Any delays can disrupt progress at treatment stations, causing a ripple effect throughout the production line. Extended analysis times can significantly increase costs by prolonging the duration that a cast remains in the BOS plant, which in turn prolongs energy consumption required to maintain the material at the desired temperature.

Moreover, delays in analysis reduce the capacity to process new casts arriving from the blast furnace, slowing overall production. This inefficiency can impact the production schedule on a larger scale, leading to missed deadlines and potential disruptions in the supply chain. Such disruptions can escalate costs and adversely affect the company's financial performance.

From a safety and compliance perspective, it is crucial that the analysis reported is both accurate and precise. This ensures that the correct grades of steel are produced, meeting customer specifications and maintaining high product quality.

To mitigate these risks, ensure customer satisfaction, and maintain smooth operations, the Spectroscopy Lab must prioritize rapid and precise analysis. This focus is essential not only for the efficient functioning of the BOS plant but also for upholding Tata Steel's commitment to delivering high-quality products in a timely manner (Hidayat, et al., 2021).

10 Quantifying Wastes

The wastes identified in Port Talbot's Spectroscopy Lab at Tata Steel have significant business implications. Although these wastes are not visible to lab staff, they impact the cost of each cast, which has an expected total cost. The Basic Oxygen Steelmaking plant requires lab results within a 7-minute turnaround time. Delays in analysis can incur additional costs due to the heat and energy needed to keep molten iron at the correct temperature, reduce capacity of plant from the inability to keep up with blast furnaces, and the incorrect addition of alloying elements which could lead to further complications (Hagström, et al., 2023).

Moreover, such delays can lead to costly downgrading or scrapping of entire casts due to insufficient alloying elements. This not only increases operational expenses but also risks leaving Tata Steel Port Talbot without specific grades of steel required by external customers, such as Jaguar Land Rover, BMW, and Hyundai. This potential shortfall can disrupt supply chains and impact customer satisfaction, further emphasizing the critical need for timely and accurate analysis.

11 Conclusion

In conclusion, the investigation into the Spectroscopy Lab's testing process has revealed several factors contributing to increased testing times. By collaborating with both customers and internal teams, significant areas of inefficiency were identified and analysed. This collaborative approach facilitated the implementation of targeted improvements aimed at optimizing the testing process and reducing turnaround times.

The adoption of miller tip life cycles, 5S housekeeping protocols, and a kanban system demonstrates a strategic approach to enhancing lab efficiency. Despite significant progress in reducing testing times and improving the consistency of steel testing, persistent challenges continue to impact the lab's performance. These challenges include issues related to lab setup, software functionality, and departmental culture. Addressing these ongoing issues remains crucial for further optimizing the testing process and achieving operational excellence.

Upcoming changes at Tata Steel UK, which may include additional investments in the labs, are anticipated to address these challenges. Continued efforts, along with ongoing monitoring and evaluation, will be essential for further enhancing the testing process and ensuring sustained improvements.

This study ultimately underscores the importance of continuous quality improvement initiatives in maintaining the accuracy and reliability of steel testing. Such initiatives are crucial for supporting informed decision-making and enhancing overall operational efficiency within the organization.

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