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Improving Overall Equipment Effectiveness

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EliteClean Innovations
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Research information

Bachelor thesis:
Improving Overall Equipment Effectiveness of EliteClean Innovations

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Preface

Dear reader,

I'm pleased to present this thesis, which marks the end of a significant academic journey filled with challenges and achievements. This work showcases the research, learning, and hard work that went into its creation.

I'd like to express my sincere gratitude to my supervisor at the company. Their guidance, support, and expert insights played a crucial role in shaping this research. I've learned a lot from them and I'm thankful for their help.

I also want to thank all the colleagues I worked with at the company. They generously shared their time and knowledge to assist with my research. Their contributions were invaluable to completing this thesis.

I can't forget to thank my first university supervisor, Dr. Niels Pulles. His advice, feedback, and suggestions were instrumental in improving the quality of this work. His mentorship has greatly enhanced my research skills.

I also owe a big thank you to my secondary supervisor, Dr. Ipek Seyran Topan. Their guidance and insights helped refine the focus of this thesis and improved its overall quality.

During times when things got tough, the support of my family and friends was a constant source of strength. Their encouragement helped me overcome challenges throughout this journey. I'm truly grateful to have them by my side.

As I reflect on this journey, I'm thankful for the opportunities I've had and the people who've supported me along the way.

Management Summary

In the highly competitive manufacturing world, companies constantly strive to enhance their productivity and efficiency to maintain their market position. EliteClean Innovations, a multinational company operating in the household and consumer goods industry, is no exception. With a significant presence in Egypt and a focus on producing high-quality and innovative products, the company recognizes the importance of operational excellence in achieving its strategic objectives.

One of the key challenges that EliteClean Innovations faces in its manufacturing environment is machine breakdowns and their impact on Overall Equipment Effectiveness (OEE). Despite being a leader in the industry, the aerosol line in EliteClean Innovations has been struggling to achieve its target OEE of 85%. Over the past six months, the average OEE of the aerosol line has been around 78%, indicating a performance gap that needs to be addressed.

The analysis of recorded data reveals seven main reasons for machine downtime in the aerosol line: small stops, changeover time, malfunctions, planned maintenance, production failures, speed loss, and training and meetings. Each of these factors contributes to the overall decrease in OEE and presents opportunities for improvement.

The research utilizes a combination of literature review and methodology, including the analysis of concepts such as Single-Minute Exchange of Die (SMED), the 5S methodology, and the "why" analysis. Additionally, semi-structured interviews were conducted with key personnel involved in the operations, maintenance, and management of the aerosol line. The insights gained from these interviews and data analysis provided evidence-based recommendations to improve OEE and optimize the aerosol line's performance.

Table I: Recommended Solutions

Bottleneck	Recommended Solutions
Speed Loss	Replace the one-direction valve with a two-direction valve in the filler machine
Small Stops	Improve valve inspection and quality control processes
Changeover Time	Increase the number of personnel assigned to changeovers; Implement a comprehensive preparation process; Standardize procedures; Utilize visual aids
Production Failures	Restore the machine to its optimal condition; Replace key components; Implement preventive maintenance practices

The research proposes several solutions to improve the Overall Equipment Effectiveness of the aerosol line in EliteClean Innovations. These include replacing the one-direction valve with a two-direction valve to address speed loss, implementing improved valve inspection and quality control processes for reducing small stops, optimizing changeover processes through increased personnel, comprehensive preparation, task standardization, and visual aids, and addressing production failures through thorough maintenance, component replacement, preventive maintenance practices, and operator empowerment through autonomous maintenance.

Table II: Recommendations

Bottleneck	Recommendations
Speed Loss	- Collaborate with the production team and equipment supplier for seamless implementation of the new valve - Implement regular monitoring and maintenance of the valves to sustain improvements and prevent issues
Small Stops	- Establish an improved valve inspection and quality control process - Collaborate with the valve supplier to improve packaging and transportation methods
Changeover Time	- Increase the number of personnel assigned to changeovers - Implement a comprehensive preparation process before changeovers - Optimize task allocation and enhance communication and coordination among team members - Standardize procedures and utilize visual aids to streamline changeovers
Production Failures	- Conduct thorough maintenance and repairs to restore the machine to its optimal condition - Replace deteriorated components with suitable spare parts - Empower operators through autonomous maintenance - Implement preventive maintenance practices and establish regular inspection, lubrication, and minor adjustments - Monitor and evaluate the implemented solutions and conduct regular performance reviews to sustain improvements and prevent issues

To optimize the aerosol line's performance, the research recommends collaborating with suppliers, implementing regular monitoring and maintenance, and sustaining improvements. Specifically, for speed loss, collaboration with the production team and suppliers is advised. For small stops, improving valve inspection and collaborating with suppliers is crucial. To reduce changeover time, increasing personnel, implementing a comprehensive preparation process, and utilizing visual aids are recommended. For production failures, thorough maintenance, component replacement, preventive maintenance practices, and operator empowerment through autonomous maintenance are suggested. Regular performance reviews and monitoring are emphasized to ensure sustained improvements.

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1. Introduction:

In the fast-paced world of manufacturing, companies always aim to enhance their productivity and efficiency to stay competitive. This is particularly true for EliteClean Innovations company that is a multinational company operating in the household and consumer goods industry. The company has a significant presence in Egypt, where it manufactures and distributes a variety of products like cleaning agents, air fresheners, and insecticides. The company is a leader in its industry and has a long history of producing high-quality and innovative products. Its operations in Egypt are a key part of its global network and it always invests in its people and processes to maintain its position as a market leader. In their effort for their quest for operational excellence, the company has directed its attention towards a challenge that is faced in the manufacturing environment – machine breakdowns and their impact on Overall Equipment Effectiveness (OEE). By closely examining the issue, the company aims to discover the underlying cause of machine breakdowns and explore effective strategies to enhance OEE to elevate its manufacturing performance.

1.1. Problem Identification and Problem Cluster:

The aerosol line in EliteClean Innovations faces significant challenges in achieving its target Overall Equipment Effectiveness of 85%. This target of 85% has been established based on industry benchmarks, where it is considered a world-class target. Over the last six months, the average OEE of the aerosol line has been around 78%, deviating from the desired target. This deviation is primarily attributed to the frequent downtime experienced by the machines operating on the line. The core problem addressed in this thesis pertains to the suboptimal OEE of the aerosol line in EliteClean Innovations' manufacturing facility.

To improve the OEE and align it with the desired target, it is crucial to identify and address the key bottlenecks affecting the aerosol line's performance. This involves a systematic examination of the data and an in-depth investigation of the underlying factors contributing to machine downtime.

Through a systematic examination of the data and an in-depth investigation of the underlying factors contributing to machine downtime, this paper will uncover insights to support evidence-based decision-making. By successfully addressing the identified bottlenecks, EliteClean Innovations will be able to enhance its operational performance, minimize unnecessary downtime, and reach its target OEE.

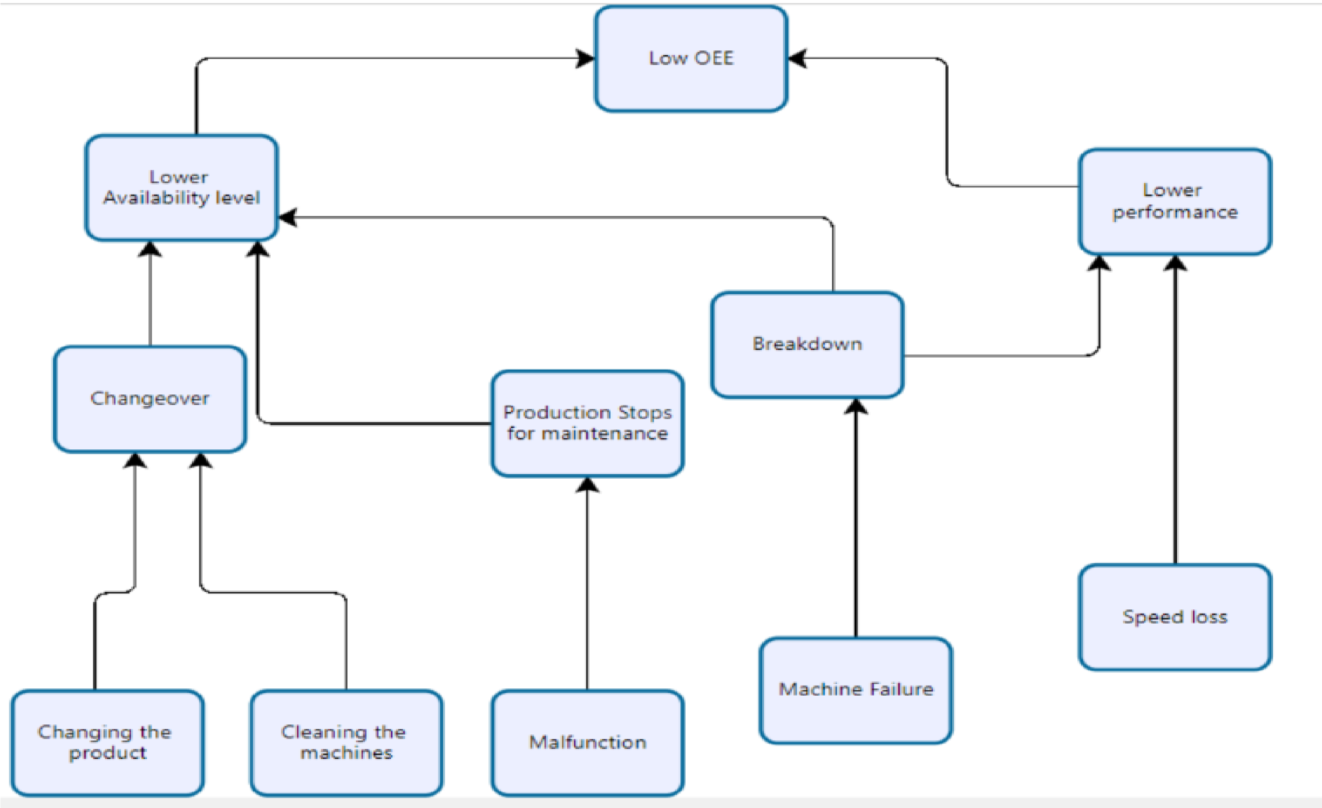

Figure 1 Problem Cluster

1.2. Overall Equipment Effectiveness

Overall Equipment Effectiveness is a crucial performance metric that provides insights into the effectiveness and productivity of the aerosol line at EliteClean Innovations. It combines three key factors: Availability, Performance, and Quality. This section will analyze the OEE of the aerosol line based on the provided data from the last six months.

The company provided separate Excel files containing the data collected by the responsible individuals within the company. The data covered the period from November 2022 to April 2023 and included information on machine breakdowns, including breakdown time, duration, criteria, the specific machine involved, and the affected machine part. The files also included a section for comments and notes provided by the responsible team members. All the data were combined into a single Excel file and began the process of cleaning, organizing, and sorting the dataset to conduct the analysis.

Availability represents the actual production time compared to the planned production time, considering any downtime or stoppages. To determine the Availability of the aerosol line over the past six months, the provided data was examined. The scheduled production time for this period was 79,778 minutes, while the total recorded downtime amounted to 14,425 minutes. By subtracting the total downtime from the scheduled time and dividing it by the scheduled time, the result was an Availability rate of 82%. This indicates that the line has been operating for 82% of the total planned production time, taking into account any downtime due to breakdowns, changeovers, or maintenance activities.

Performance measures the actual production speed compared to the ideal or maximum possible speed. In the company's case, the ideal production speed for the aerosol line is 200 products per minute. Considering the scheduled production time of 79,778 minutes and subtracting the total downtime of 14,425 minutes, the actual running time of the machine is 65,353 minutes.

During this operational time, the actual production output was 1,034,757 dozens, which corresponds to 12,417,084 individual products. This actual output represents approximately 95% of the target production, which would have been achieved if the machine had run continuously at the ideal speed of 200 products per minute throughout the operational time.

Therefore, based on the data provided, the Performance of the aerosol line during the evaluated period is estimated to be around 95% of the target production, accounting for the achieved output of 12,417,084 products out of 13,070,600 products.

Performance Metric	**Value**
Target Production	1,089,217 dozens (13,070,600 products)
Ideal Production Speed	200 products per minute
Scheduled Production Time	79,778 minutes
Total Downtime	14,425 minutes
Actual Running Time	65,353 minutes
Actual Production Output	1,034,757 dozens (12,417,084 products)

Quality assesses the proportion of good-quality products produced compared to the total number of products. In the case of the aerosol line at the company, the Quality factor is determined to be 100%. This signifies that the line has consistently produced products meeting the specified quality standards, and any defective or non-conforming products have been rejected during the production process. Due to effective quality control measures in place, there were no defective products among the total production output of 12,417,084 products. All of the produced items met the required quality criteria, resulting in a Quality factor of 100%. This achievement reflects the company's commitment to maintaining high standards and ensuring that only products of acceptable quality are released from the production line.

Based on the above calculations, we can determine the overall OEE for the aerosol line:

OEE = Availability × Performance × Quality

OEE = 82% × 95% × 100% = 78.1%

The calculated OEE of 78.1% indicates the overall efficiency of the aerosol line at EliteClean Innovations over the past six months. This value implies that the line has room for improvement to reach the company's target OEE of 85%.

Analyzing the individual components of OEE can help identify areas for improvement. For instance, strategies can be implemented to reduce downtime, enhance machine availability, optimize changeover processes, and minimize equipment breakdowns. Similarly, efforts can be made to further improve performance by reducing speed loss, addressing minor stops, and optimizing production speeds. Furthermore, maintaining the excellent quality performance observed can contribute to overall OEE improvement.

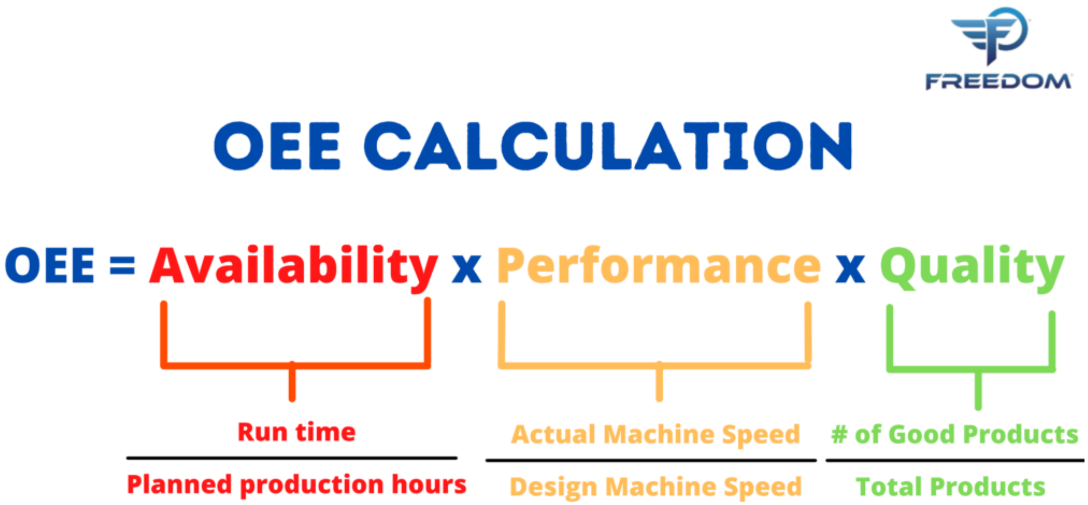

Figure 2 OEE Calculation

1.3. Production Process

The production process of the aerosol line involves a series of steps, each performed by specific machines, to ensure the successful manufacturing of the products. As seen in Figure 3, the process begins with the depalletizer, which unloads containers, typically empty aerosol cans, from pallets and feeds them into the production line. The containers then move to the filler machine, where the precise formulation of the product is dispensed into each container, ensuring accurate filling levels and consistent measurements.

After filling, the containers proceed to the crimping machine, which securely seals the top of the container to prevent any leakage. Next, the containers pass through the valve machine, where the valve is inserted into each container, enabling the release of the aerosol product. If the product requires a propellant, such as compressed gas, a gas filler machine injects the propellant into the container, providing the necessary pressure for product release.

To ensure quality control, the weight of each container is checked to verify the correct amount of product and propellant. Additionally, containers undergo a water bath machine to detect potential leaks by submerging the containers and observing air bubbles or other indicators. Following the water bath, a dryer machine removes any moisture from the containers.

Labels containing product information, branding, and regulatory details are applied to the containers using the labeler machine. The containers then pass through a shrink tunnel, where heat is applied to tightly shrink the labels around the containers. Depending on the production setup, containers may go through a coaster or sorter machine, which arranges and organizes them for further processing or packaging.

If the aerosol product requires an actuator, an actuator machine places the appropriate actuator, such as a spray nozzle or dispenser, onto each container. The containers then proceed to the capping machine, where the actuator is securely capped or sealed. A code machine may be employed to apply batch numbers, expiration dates, or other identification codes for traceability and quality control purposes.

Further enhancing the packaging's appearance and providing tamper-evident features, the containers pass through another shrink machine. In some cases, additional stickers or promotional materials are applied using the sticker machine. Finally, the containers reach the end of the production line, where they are ready for packaging, storage, or distribution. This detailed and comprehensive process ensures the efficient and precise manufacturing of aerosol products, meeting the highest quality standards.

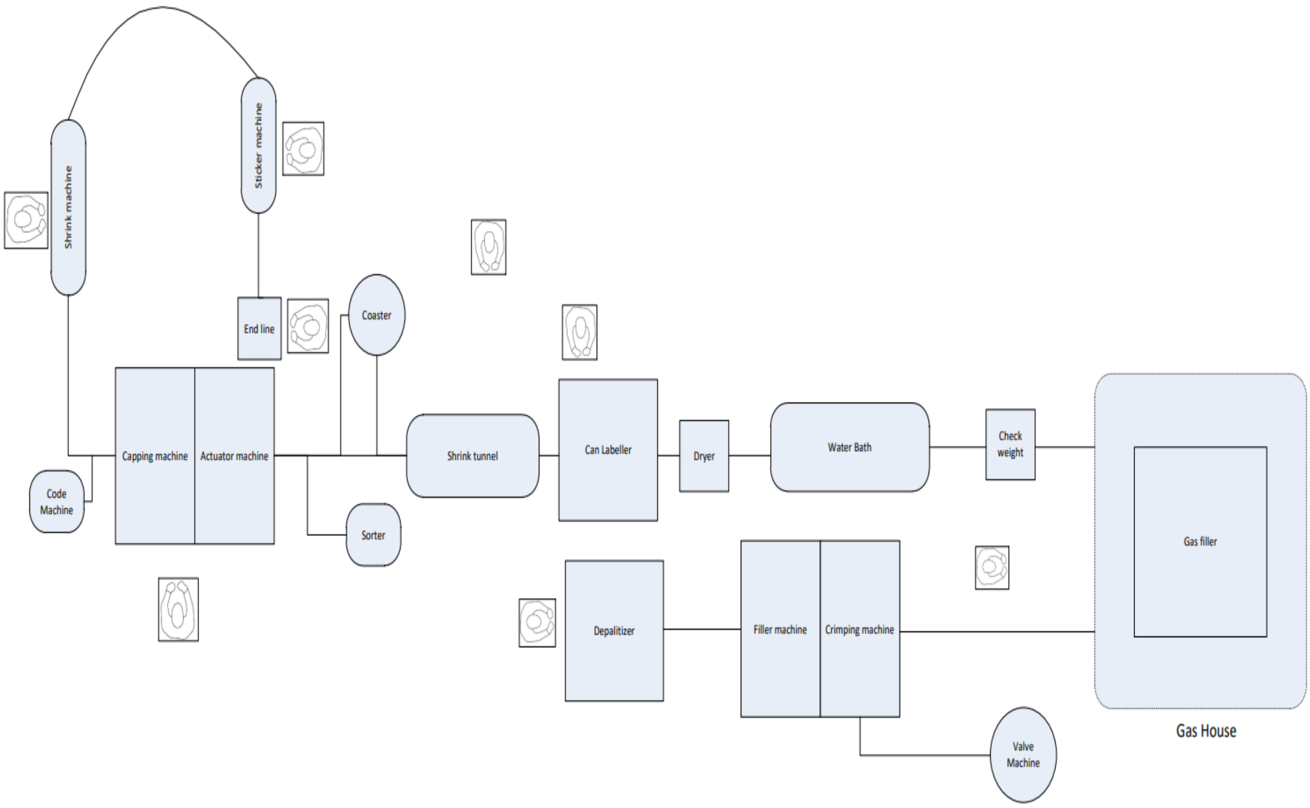

Figure 3 Aerosol Line Map Provided by the Company

1.4. Research Approach

This section covers the research question, the sub-research questions, and the aim of the research. The research question aims to increase the OEE of the aerosol line in the company.

Research Question: What are the main bottlenecks affecting the OEE of the aerosol line in EliteClean Innovations, and how can they be addressed to achieve the target OEE of 85%?

The research question aims to identify the key challenges and obstacles that are causing a lower OEE in the aerosol line of EliteClean Innovations. The objective is to understand the specific bottlenecks and their impact on OEE and propose potential solutions to address them to achieve the desired target OEE which is 85%. To get answers to the research question, the following sub-research questions were formulated:

1- *What are the specific reasons behind the machine downtime in the aerosol line of EliteClean Innovations?*
2- *How does machine downtime impact the overall OEE of the aerosol line?*

These Sub-Research questions focus on investigating the reasons behind the machine downtime in the aerosol line of EliteClean Innovations .The aim is to identify the specific factors contributing to machine downtime and explore its impact on the overall OEE. This sub-research question seeks to discover the underlying causes of machine downtime, quantify its effect on OEE, and assess the potential costs associated with it. By gaining insights into the specific reasons behind machine downtime, the research aims to propose strategies to minimize downtime and improve OEE.

3- *What are the key factors influencing the changeover time in the aerosol line of EliteClean Innovations ?*
4- *How can these bottlenecks be addressed to increase the OEE?*

These Sub-Research questions examine the key factors influencing the changeover time and cleaning process in the aerosol line of EliteClean Innovations . The objective is to identify the factors that contribute to longer changeover times and suboptimal cleaning processes and their impact on OEE. This sub-research aims to explore the elements of changeover that can be improved to reduce the time taken and improve efficiency. By identifying the key factors and potential areas for improvement, the research seeks to propose strategies and techniques to optimize changeover time and the other bottlenecks mentioned, leading to improved OEE.

The approach to tackling the problem at hand will involve a structured methodology in both analysis and reporting. The report will follow a defined structure, encompassing various key sections to provide a comprehensive understanding of the issue and propose effective solutions.

The analysis will begin with Chapter 2- Context Analysis, which offers an overview of the manufacturing environment and highlight the four problems with the highest percentages of breakdowns. This analysis will be based on the data provided, allowing for a focused examination of the challenges specific to the aerosol line.

Following the Context Analysis, a Literature Review was conducted in Chapter 3. This involved extensive research and review of relevant academic papers and articles, covering topics such as machine breakdowns, Overall Equipment Effectiveness (OEE) improvement, and best practices in the manufacturing industry. The literature review will serve as a foundation, providing valuable insights and helping in finding solutions.

Moreover, the 4th chapter will discuss the methodology used in this thesis. The focus will be on data analysis, interviews, and observations.

Subsequently, the report will delve into the Problem Analysis in the 5th chapter. The focus will be on identifying and discussing the key problem of the four identified bottlenecks, which contribute to machine breakdowns and hinder the OEE of the aerosol line. This section will present the findings obtained through the analysis of gathered data, interviews, and observations. Then, it will provide key solutions for every problem.

Lastly, the report will conclude with a Recommendations section that will provide broader suggestions for enhancing overall manufacturing performance.

Throughout the report, a concise analysis will be presented. This analysis would be supported by relevant data, references, and visualizations generated using Excel. This approach will ensure a comprehensive understanding of the problem and facilitate the identification of effective solutions.

2. Context Analysis

This section provides a context analysis of the aerosol line at EliteClean Innovations, focusing on the main bottlenecks affecting the OEE. It addresses the first part of the research question which is: "What are the main bottlenecks affecting the OEE of the aerosol line in EliteClean Innovations ?" and its sub-questions: "What are the specific reasons behind machine downtime in the aerosol line of EliteClean Innovations?" and "How does machine downtime impact the overall OEE of the aerosol line?"

Subsequently, the section explores the specific reasons behind machine downtime in the aerosol line. An analysis of the recorded data provided by the company reveals that the machine downtime can be categorized into seven different reasons, each contributing to the overall decrease in OEE. These reasons, along with their respective percentages of downtime, are as follows: small stops (32.16%), changeover time (21.03%), malfunctions (10.02%), planned maintenance (7.1%), production failures (15.04%), speed loss (12.71%), and training and meetings (1.93%). The factors with the highest percentages such as speed loss, production failures, small stops, and changeover time are examined to uncover the causes of interruptions in the production process. The reason behind these factors is that they have the highest percentages of downtime so a decrease in them will cause a significant decrease in downtime. The percentages mentioned can be found in Appendix A.

Section 2.1 will focus on the significant issue of speed loss in the aerosol line. Section 2.2 will delve into the factors contributing to the production failures. Section 2.3 will discuss the specific reasons behind small stops. Section 2.4 will discuss the 2 main factors contributing to the lengthy changeovers, which will answer the third sub-research question which is *What are the key factors influencing the changeover time in the aerosol line of EliteClean Innovations?*

By addressing the research question and its sub-questions, this context analysis provides a comprehensive understanding of the challenges affecting the OEE in the aerosol line at EliteClean Innovations. The findings derived from analyzing the data through Excel will inform subsequent sections, guiding the identification of root causes, formulation of recommendations, and ultimately, the improvement of operational efficiency and OEE in the aerosol line.

2.1. Speed Loss

In the aerosol line, a significant issue affecting production speed is the loss of speed as a result of containers not attaining the required weight. This problem is due to the use of a one-direction valve in the filler machine, which results in inconsistent filling and inaccurate weight measurements. The speed loss caused by this issue significantly decreases the OEE of the aerosol line. When containers do not reach the required weight, it reduces production efficiency and effectiveness. The line experienced increased downtime as a result of the need for manual interventions and adjustments to increase the weight. This slows down the overall production speed and also decreases the availability and performance of the line, contributing to a lower OEE. With reducing the speed loss, the aerosol line can operate at its full potential, maximizing the utilization of resources and optimizing production output. By consistently achieving the required weight for each container, the productivity and performance of the line are enhanced, resulting in higher OEE values, which positively impact the overall operational efficiency and profitability of the aerosol line.

2.2. Production Failure

Among the reasons for machine downtime, production failures account for 15.04% (Appendix A) of the total downtime in the aerosol line at EliteClean Innovations, with approximately 63% of these production failures attributed to a specific machine, the Water Bath Machine.

The analysis of production failures reveals two main causes for these issues. Firstly, containers dropping from the Water Bath Machine contribute to interruptions in the production process, requiring downtime to address the fallen containers and resume operations. This poses a significant challenge to productivity as it stops the entire line.

Secondly, small malfunctions within the Water Bath Machine itself also contribute to production failures. These malfunctions lead to operational disruptions and downtime. Identifying and resolving these malfunctions is essential to minimize production failures and improve overall efficiency.

The percentage of production failures in the Water Bath Machine emphasizes the need for focused attention on this particular machine. Addressing the causes of container-dropping incidents and resolving the underlying malfunctions within the machine are critical steps toward reducing production failures and increasing machine uptime, which will increase the OEE.

2.3. Small Stops

According to the classification of the company, Small stops are stops that are less than 5 minutes. Small stops account for approximately 32.16% (Appendix A) of the total machine downtime in the aerosol line. Among these small stops, around 31%, are attributed to problems associated with valves. This makes the valve-related issues a primary focus for improvement due to their substantial effect on machine downtime.

The analysis indicates that the valve problems, such as misalignment or malfunctions, make the valves unsuitable for insertion into the product, leading to interruptions in the production process. While other reasons for small stops exist, they are insignificant in terms of their overall impact on machine downtime and are easier to address.

The remaining small stops can be attributed to issues such as tanks not being adequately filled, minor problems with the containers, minor problems with the machines, and other insignificant stops. These factors are relatively more straightforward to resolve compared to valve-related problems.

By dedicating efforts towards solving valve-related issues, EliteClean Innovations can significantly reduce the percentage of small stops and improve the efficiency of the aerosol line. Implementing measures to ensure proper valve alignment and functionality will be important to minimize interruptions in the production process caused by valve-related problems.

While efforts to optimize other small stops issues, the primary focus will be on resolving the valve problems due to their higher prevalence and impact on machine downtime.

2.4. Changeover

Changeover forms a huge portion of machine downtime in the aerosol line at EliteClean Innovations , accounting for approximately 21.03% (Appendix A) of the total downtime. After analyzing the data provided by the company, two main factors were concluded as the contributors to changeover time: transitioning between products and changing the pulley of the shrink machine.

Approximately 64% of the changeover time is allocated to transitioning from one product to another and conducting the required cleaning between them. This includes activities such as clearing residual products, cleaning equipment, and sanitizing the line before introducing a new product. Although these changeovers are planned stops, they still contribute to machine downtime and pose challenges to achieving the desired OEE.

The remaining 26% of the changeover time is attributed to changing the pulley of the shrink machine. While this activity is also a planned stop, it requires specific adjustments and fine-tuning, resulting in additional downtime during the changeover process.

Addressing changeover time and minimizing waste associated with these planned stops is crucial for improving the efficiency of the aerosol line. By focusing on eliminating waste and implementing strategies to decrease changeover time, EliteClean Innovations can effectively reduce machine downtime and optimize production processes. The next section will briefly explain the theories that will be used to decrease the changeover time and the other bottlenecks to increase the OEE of the Aerosol line.

2.5. Chapter Conclusion

In this context analysis, the main bottlenecks affecting the OEE of the aerosol line at EliteClean Innovations were identified, answering the first part of the research question "What are the main bottlenecks affecting the OEE of the aerosol line in EliteClean Innovations?". Speed loss, production failures, small stops, and changeover time were found to have the highest percentages of downtime, significantly impacting the line's efficiency.

The sub-research questions "What are the specific reasons behind machine downtime in the aerosol line of EliteClean Innovations ?" and "How does machine downtime impact the overall OEE of the aerosol line?" are addressed in this context analysis. The main reasons behind machine downtime are speed loss, production failures, small stops, and changeover time. They were found to have the highest percentages of downtime, significantly impacting and decreasing the availability factor of the aerosol line, reducing the OEE.

Speed loss results from inconsistent filling due to a one-direction valve in the filler machine, reducing production speed and OEE. Production failures, primarily attributed to the Water Bath Machine, cause interruptions and downtime. Small stops, often related to valve issues, contribute to frequent interruptions in the production process. Changeover time, a significant portion of downtime, involves transitioning between products and changing the shrink machine's pulley.

The next section will be a literature review, briefly explaining the theories to decrease changeover time and other bottlenecks, leading to improved operational efficiency and OEE for the aerosol line at EliteClean Innovations.

3. Literature Review

This section is essential in this thesis as it provides a theoretical foundation and practical strategies to address the research question: "What are the main bottlenecks affecting the OEE of the aerosol line in EliteClean Innovations, and how can they be addressed to achieve the target OEE of 85%?"

Through a review of existing literature, the chapter explores methodologies like SMED, the 5S methodology, and the "why" analysis, known for improving OEE in various industries. These approaches offer valuable insights and proven strategies to optimize processes, minimize downtime, and foster continuous improvement.

The Why Analysis will help in exploring the root causes of the machine downtime. The 5s methodology and SMED methods will help in solving the problem and providing the necessary recommendations to the company. By understanding and applying these methodologies, EliteClean Innovations can effectively address the identified bottlenecks and achieve the desired OEE of 85% for the aerosol line.

3.1. 5s methodology

The 5S methodology is a fundamental Lean Six Sigma tool used to improve workplace organization and efficiency. It encompasses five principles, each starting with the letter "S," which are Sort, Set in Order, Shine, Standardize, and Sustain (Adeodu, Kanakana, & Maladzhi, 2021). This methodology has been widely adopted by organizations across various industries to enhance productivity, eliminate waste, and create a safer and more organized work environment.

The first step in the 5S methodology is Sort, which involves removing unnecessary items from the workplace. It requires employees to identify and separate essential items from those that are rarely used or not needed at all. By eliminating clutter and non-essential items, organizations can optimize space utilization and improve workflow efficiency.

The second step is Set in Order, which focuses on organizing and arranging necessary items logically and ergonomically. This involves defining specific locations for tools, equipment, and materials to ensure easy accessibility and minimize time wasted searching for them. Implementing visual cues such as labels and signage further aids in maintaining an organized workplace.

The third step, Shine, emphasizes cleanliness and regular maintenance of the workspace. It involves establishing cleaning routines and standards to uphold a neat environment. By promoting cleanliness, organizations can prevent the accumulation of dirt, dust, and debris, which can negatively impact both productivity and employee morale.

The fourth step, Standardize, aims to establish consistent processes and procedures. It involves creating clear guidelines and documentation for tasks, workflows, and responsibilities. Standardization helps reduce variability and ensures that everyone follows best practices, leading to improved efficiency, quality, and safety.

The final step, Sustain, is about maintaining the improvements achieved through the previous steps. It requires the active involvement of employees and the integration of the 5S principles into the organization's culture and daily routines. Regular audits, employee training, and continuous improvement efforts help sustain the benefits of 5S over the long term.

3.2. Single-Minute Exchange of Die

SMED is a lean manufacturing methodology aimed at reducing the time required for equipment or machine setup and changeover (Benjamin, Murugaiah, & Marathamuthu, 2013). SMED is usually applied to minimize small stoppages in the seaming process. The stages of SMED outlined in the article provide a systematic approach to tackle the issue.

The first stage involves observation and measurement. The total time loss caused by small stoppages is carefully observed and measured. A small stop observation chart is used to record the time taken for each step of the small stop process. This data serves as a baseline to understand the current situation and identify areas for improvement.

The second stage focuses on separating internal and external activities. Internal activities are activities that can only be performed when the machine is stopped, while external activities are activities that can be carried out while the machine is running. The goal is to convert as many internal activities as possible into external activities. This shift eliminates the downtime associated with small stoppages and improves efficiency.

In the third stage, internal activities are streamlined to reduce the time required for each task to a minimum. While the article does not provide specific details for the seaming process, this stage emphasizes applying lean principles, simplicity, and minimizing investment to find solutions. It requires the skills and expertise of lean manufacturing practitioners to optimize internal activities effectively.

Once internal and external activities are separated and streamlined, the fourth stage focuses on parallelization. This means synchronizing the remaining internal and external activities to run in parallel (Benjamin et al., 2013). By coordinating these activities, internal tasks can be performed concurrently with the setup or changeover process, minimizing overall downtime and increasing efficiency.

The final stage of SMED is continuous improvement. It emphasizes the need to continually monitor and evaluate the setup process to identify further opportunities for improvement. This stage promotes a culture of continuous learning and refinement, allowing companies to iteratively enhance their setup or changeover processes, reducing downtime, and optimizing operational efficiency.

In summary, SMED is a methodology that provides a structured approach to reducing setup and changeover time in manufacturing processes. By following the stages outlined in the article, companies can effectively minimize small stoppages and improve overall productivity. The stages include observation and measurement, separating internal and external activities, streamlining internal tasks, parallelization, and a focus on continuous improvement. Applying SMED enables companies to enhance their operational efficiency and flexibility in the manufacturing environment.

3.3. The Why Analysis

The "why" analysis, as part of the Ishikawa diagram, is a valuable approach for identifying the cornerstone root causes of a problem (Suárez-Barraza & Rodríguez-González, 2019). By systematically probing and questioning each identified cause, this analysis aids in uncovering deeper layers of causation and understanding the underlying issues. This methodological approach encourages critical thinking, facilitates thorough analysis, and enables the identification of overlooked factors contributing to the problem at hand.

According to Suárez-Barraza and Rodríguez-González (2019), the "why" analysis provides a structured framework for tracing cause-and-effect relationships within different categories of the Ishikawa diagram. This systematic approach not only treats the symptoms of a problem but also addresses the root causes, aligning with the principles of continuous improvement and quality management. By addressing these root causes, organizations can implement more effective solutions and preventive measures, minimizing the recurrence of problems in the long term.

3.4. Chapter Conclusion

The literature review explored various methodologies that have proven effective in improving Overall Equipment Effectiveness (OEE) in manufacturing industries. These methodologies include the 5S methodology, Single-Minute Exchange of Die (SMED), and the "why" analysis.

The 5S methodology focuses on workplace organization and efficiency, promoting a safer and more organized work environment. By implementing the principles of Sort, Set in Order, Shine, Standardize, and Sustain, EliteClean Innovations can enhance productivity, eliminate waste, and optimize the production process.

SMED is a lean manufacturing methodology aimed at reducing setup and changeover time. By observing, separating internal and external activities, streamlining internal tasks, parallelizing activities, and continuously improving the setup process, EliteClean Innovations can minimize small stoppages and improve operational efficiency.

The "why" analysis, as part of the Ishikawa diagram, aids in identifying the root causes of problems. By systematically probing and questioning each cause, EliteClean Innovations can gain a deeper understanding of the underlying issues, particularly in the cases of speed loss and production failures.

To address the research question, the 5S methodology and SMED will be employed to reduce changeover time and small stops, respectively. These efforts will contribute to increasing the OEE of the aerosol line. Additionally, the "why" analysis will be used to analyze the root causes of speed loss and production failures, enabling the company to implement its targeted solutions.

By integrating the insights and strategies from the literature review, the company can effectively address the identified bottlenecks, optimize the production process, and work towards achieving the target OEE of 85% for the aerosol line. These methodologies provide a theoretical foundation and practical framework to guide the improvement initiatives and foster continuous enhancement in operational efficiency and OEE.

4. Methodology

This section explains the methods employed in this thesis to reduce downtime and increase the OEE of the aerosol line in EliteClean Innovations. The primary methodologies utilized are Data Analysis, Interviews, and Observations.

Data Analysis:

Data analysis is a critical step in this thesis as it provides a comprehensive understanding of the reasons for machine stops and downtime. The data provided by the company includes a comments column for each stop, offering valuable information on the main reasons behind the stoppages. By analyzing this data, the exact problems causing the small stops were identified, which will guide the formulation of targeted solutions.

Furthermore, data analysis is central to the "why" analysis, which helps us understand the root causes of speed loss and production failures. By systematically probing and questioning each cause, the underlying issues can be uncovered and effective strategies for addressing these challenges can be developed.

Interviews:

The purpose of conducting interviews with stakeholders, including personnel directly involved in the aerosol line operations, is twofold. Firstly, interviews aim to validate the reliability of the data provided by the company. By cross-referencing the data findings with real-life experiences, the accuracy and credibility of the data can be ensured. This validation is essential as it forms the basis for subsequent analysis and decision-making.

Secondly, interviews serve as a valuable tool during the problem analysis section. By gathering insights and perspectives from the individuals working on the aerosol line, the challenges and bottlenecks faced in the actual production environment could be better understood. These firsthand accounts help uncover the key problems of each section affecting the OEE, providing crucial information for formulating effective solutions.

Observations:

Observations were conducted to help uncover the main reasons behind the lengthy changeovers since it is not explained explicitly in the data provided. By closely examining the changeover process, specific steps or tasks that contribute to extended downtime can be pinpointed, providing valuable insights to optimize the changeover procedures further.

Moreover, observations play a pivotal role in testing the effectiveness of the changeover process before and after implementing the recommended changes derived from the SMED technique and the 5S methodology. By observing the changeover procedures, efficiency can be assessed and areas for improvement can be identified. Additionally, observations will help in calculating the percentage of decrease in changeover time after implementing the proposed solutions.

In summary, the methodology employed consists of Interviews, Observations, and Data Analysis. Interviews aid in data validation and problem analysis, while observations contribute to changeover process assessment and identification of reasons behind lengthy changeovers. Data analysis serves as the foundation for identifying the root causes of machine stops and aids in formulating targeted solutions. Through the integration of these methodologies, the aim is to optimize the aerosol line's performance, reduce downtime, and achieve the target OEE of 85% for EliteClean Innovations.

4.1. Interviewees

This section will focus on the semi-structured interviews conducted with key personnel involved in the aerosol line operations, maintenance, and management. The conducted interviews will serve as a crucial means to gain deeper insights into the identified problems and understand their underlying causes.

The interviews will be conducted in a semi-structured manner, allowing for flexibility and adaptability to explore specific topics in more detail while still maintaining a consistent path. This approach enables the interviewer to follow a predefined set of questions while also allowing for open-ended discussions and the exploration of additional relevant information that may arise during the interview process (Cooper&Schindler, 2023). The interview protocol can be found in Appendix D.

During the interviews, participants will be encouraged to share their experiences, observations, and suggestions regarding the bottlenecks affecting the aerosol line's OEE. The interview questions will cover a range of topics.

Table 1 Interviewees

Interviewees	**Purpose of Interview**
Personnel working on the aerosol line	Gather insights into bottlenecks faced daily by the aerosol line. Gather information about malfunctions reasons and machines that are prone to defects. Getting to know the inefficiencies faced by the line and how the problems can be addressed from their point of view.
Operations and Manufacturing Manager	Obtain a broader perspective on the overall performance and strategic goals of the company. Know the expectation of the line and gather his insights about the reason for underperformance.
Mechanics and Maintenance Consultant	Worked for the company for a long time years as a mechanic and then as a maintenance manager before retiring. He could provide valuable information about the history of the machines and his recommendations would be extremely valuable.
Maintenance Manager	Understand current maintenance practices and priorities. His recommendations regarding the machines are valuable.

By interviewing these individuals, a comprehensive understanding of the aerosol line's challenges, maintenance practices, and potential improvement opportunities can be gained. This information can then be used to formulate effective strategies and recommendations to address the bottlenecks and achieve the target OEE of 85%.

4.2. Interviews Results

Addressing the main bottlenecks impacting the OEE of the aerosol line in EliteClean Innovations is crucial for achieving the target OEE of 85%. This section focuses on answering the first part of the research question: "What are the main bottlenecks affecting the OEE of the aerosol line in EliteClean Innovations?" Through interviews with stakeholders and data analysis, the root causes behind machine downtime, speed loss, small stops, and production failures have been identified. Understanding these underlying issues is essential in formulating effective solutions to enhance the efficiency and performance of the aerosol line.

Table 2 Problems Mentioned by Stakeholders

Personnel working on the aerosol line	• Shrink machine Pulley • Water bath machine malfunctions • Container handling • Speed Loss • Containers dropping • Inadequate planning
Operations and Manufacturing Manager	• Low availability • Lengthy Changeovers • Supplier decreased the quality • Personnel doesn't take initiatives
Mechanics and Maintenance Consultant	• Some parts lack maintenance • Old machines
Maintenance Manager	• Skill Gap between the personnel working on the aerosol line • Small amount of workers on the line • Small stops • Valve Problems

These problems were identified through interviews conducted with stakeholders involved in the aerosol line, including personnel working directly on the line, the operations and manufacturing manager, the mechanics and maintenance consultant, and the maintenance manager. Their insights and perspectives shed light on the specific challenges and issues impacting the performance and efficiency of the aerosol line.

By incorporating the feedback and experiences of these stakeholders, a comprehensive understanding of the problems affecting the aerosol line can be obtained. This valuable input from the individuals directly involved in the line's operations and maintenance enables a holistic approach to identifying and addressing the bottlenecks and obstacles that hinder the achievement of optimal performance and target OEE.

5. Problem Analysis

This chapter delves into the thorough analysis of the aerosol line at EliteClean Innovations to identify and address key problems affecting its efficiency and productivity. The goal is to uncover the root causes behind the speed loss and production failures, as well as find effective solutions for the small stops and lengthy changeovers.

Section 5.1 conducts a root cause analysis using the "why" method to uncover the key problem behind the speed loss issue in the aerosol line. The analysis will culminate in the proposal of a solution aiming to improve the filling accuracy and overall efficiency.

Section 5.2 discusses the small stops problem which focuses on the valve-related issues that contribute to machine interruptions. The section will introduce the implementation of the 5S methodology as a recommended solution to optimize valve handling, including steps like sorting, setting in order, shining, and sustaining improvements.

Section 5.3 addresses the issues related to lengthy changeovers on the aerosol line. The section will propose a combined approach, utilizing both the 5S methodology and the Single-Minute Exchange of Die (SMED) methodology to streamline changeovers and reduce downtime significantly.

Section 5.4 will conduct a Root Cause Analysis (RCA). This systematic approach will involve a series of "why" questions to dig deep into the root causes behind the machine breakdowns, speed loss, and small stops. Based on the RCA findings, the section will present a comprehensive set of solutions to improve the reliability and performance of the water-bath machine.

By conducting a thorough analysis and proposing effective solutions in each section, this chapter aims to contribute to the overall enhancement of the aerosol line's efficiency and productivity, ensuring smoother operations and minimizing production interruptions, ultimately increasing OEE.

5.1. Speed Loss Problem Analysis

Key Problem:

To determine the key problem of the speed loss issue, the why analysis was used to delve deeper into the root cause of the problem. A collaborative approach was taken with the personnel working on the aerosol line and the maintenance manager. Through discussions and brainstorming sessions, the team asked a series of "why" questions to explore the underlying factors contributing to the problem. Together, answers were provided to these questions, delving deeper into the causes and effects of the issue. After multiple iterations of asking "why," the root cause was identified as the use of a one-direction valve in the filler machine. This valve lacks the necessary precision to ensure accurate and consistent filling of the containers, leading to underfilled aerosol products, which is the key problem of speed loss. The collective input and collaboration among the team members helped in the identification of this root cause.

Table 3 Overview of questions asked

Why are containers underfilled?	Because the valve in the filler machine is not accurately dispensing the required amount of aerosol product.
Why is the valve not dispensing accurately?	Because the one-direction valve currently in use lacks precision in controlling the flow of the aerosol product.
Why was the one-direction valve initially selected?	It was chosen based on its availability and compatibility with the filler machine at the time of installation.
Why does the one-direction valve result in underfilled containers?	The one-direction valve does not allow for proper adjustment of the filling process, leading to inconsistent and inadequate filling of the containers.

Key Solution:

During the analysis phase, the team engaged in brainstorming sessions to generate potential solutions for addressing the speed loss issue in the aerosol line. Through collaborative discussions and knowledge sharing, the idea of replacing the existing one-direction valve with a two-direction valve emerged as a promising solution.

The team focused their efforts on evaluating and testing the feasibility and effectiveness of the two-direction valve. Alternative valve options were not explored extensively, as the consensus among the team members was that the two-direction valve had the potential to significantly improve the OEE of the aerosol line.

To validate this hypothesis, the team conducted thorough testing and evaluation of the two-direction valve. Compatibility tests were performed to ensure seamless integration with the existing filler machine, and its performance was assessed in terms of accurate weight filling and consistency. These tests provided concrete evidence that the two-direction valve was indeed a viable solution for reducing speed loss and improving production efficiency.

The chosen solution of replacing the existing one-direction valve with a two-direction valve is not costly since the required valve is already available in the warehouse. After successful testing and evaluation, the implementation of the two-direction valve was promptly carried out, as there was no need for additional expenses to acquire the necessary equipment. This cost-effectiveness further supports the decision to implement the solution to address the speed loss issue in the aerosol line.

5.2. Small Stops Problem Analysis

Key Problem:

After conducting interviews with personnel working on the aerosol line and analysing the provided data by the company, the root cause of the small stops in the production process has been identified. These small stops, which account for approximately 32.16% of the total machine downtime, have a significant impact on the efficiency of the aerosol line.

Through the provided data and confirmed by the interviews, it was revealed that around 31% of the small stops can be attributed to issues related to valves. The primary factor causing these valve-related problems is the condition in which the valves are received. It was observed that the valves often arrive curved or folded, which hinders their proper insertion into the product. This misalignment or malfunction of the valves results in interruptions in the production process, leading to small stops.

The identification of this root cause highlights the importance of addressing valve-related issues to reduce machine downtime and improve overall efficiency. While other factors contributing to small stops exist, their impact on downtime is relatively insignificant compared to valve-related problems. This knowledge enables the company to focus its improvement efforts on resolving the root cause and mitigating the interruptions caused by valve misalignment or malfunctions.

Key Solution:

To address the root cause of valve-related small stops and improve the efficiency of the aerosol line, the implementation of the 5S methodology is a recommended solution.

In the initial step of "Sort,". the company should conduct a thorough assessment of the valve receiving process to eliminate any curved or folded valves that may cause misalignment or malfunctions, which will ensure only properly aligned and functioning valves are used in the production process.

Moving on to "Set in Order," this means establishing a standardized and efficient process for storing and handling valves. Clear labeling and dedicated storage locations for different types of valves will facilitate easy identification and retrieval, reducing the risk of using defective valves and minimizing small stops.

In the "Shine" step, the emphasis is on cleanliness and regular maintenance of the workspace. Keeping the valve storage area and the surrounding work environment clean and well-maintained will contribute to the prevention of dust and debris accumulation, ensuring that the valves are in optimal condition for insertion into the product.

Finally, the "Sustain", to sustain the results and prevent the reoccurrence of valve-related small stops, continuous monitoring and auditing of the valve handling process should be conducted. This means engaging the workforce in regular evaluations and improvements.

5.3. Changeovers Problem Analysis

Key Problems:

The identification of the key problems contributing to the lengthy changeovers in the aerosol line is based on analyzing the data provided by the company and the insightful interviews and observations conducted. Through these interviews and observations, valuable data and information were collected, providing a comprehensive understanding of the challenges and issues associated with changeovers.

Surprisingly, the data provided by the company indicated that the changeover of the pulley of the shrink machine took a full minute, which seemed unusually long for what was perceived as a relatively simple task that does not require high skill levels but rather efficient execution and speed. Additionally, the recorded 15-minute duration for the changeover between products also raised concerns regarding potential areas for improvement. These findings led the team to conduct observations to identify the specific inefficiencies and explore opportunities for enhancing the changeover process. All the Observations can be found in Appendix E.

Through interviews with personnel working on the aerosol line, it was revealed that one of the primary reasons for the lengthy changeovers is the low number of personnel assigned to the aerosol line. Most of the time, only one person is responsible for implementing the changeover process, which significantly prolongs the duration. As a result, there is a need to evaluate the staffing levels during changeovers and consider the benefits of allocating additional resources to streamline the process.

The observations provided valuable insights into the impact of personnel and quickness on the changeover process. It was observed that when one person implements the changeover, it takes 15 minutes (Table 9, Appendix E) , whereas if two persons are involved, the time is reduced to around 10 minutes (Table 10, Appendix E). This highlights the significance of having an optimal number of personnel dedicated to changeovers to improve efficiency.

Another significant contributing factor to the lengthy changeovers is the lack of preparation. During the interviews, it was mentioned by the personnel that inadequate planning and organization before initiating a changeover leads to delays and confusion during the process.

Moreover, the observations emphasized that the speed and quickness of the individuals involved play a crucial role in changing the pulley of the shrink machine (Table 10, Appendix E) . The recorded one-minute duration for this task is considered too long for such a seemingly straightforward activity. This indicates the need to assess the skills and proficiency of the personnel performing the changeover and identify ways to enhance their execution speed.

In summary, the key problems identified during the changeover problem analysis include the prolonged duration for changing the pulley of the shrink machine, the lack of preparation, and the inefficiencies in transitioning between different products. The shortage of personnel assigned to changeovers and the speed at which the tasks are executed emerged as significant factors contributing to the prolonged changeover times. By addressing these key problems the company can optimize the changeover process and reduce downtime, which will improve the overall efficiency of the aerosol line.

Key Solutions:

The first solution involves increasing the number of personnel assigned to changeovers. Through experiments where changeovers were conducted with two persons instead of one, a significant decrease of approximately 30% in changeover time was observed. The division of tasks and the ability to work simultaneously contributed to improved efficiency and reduced downtime. As a result, an increase in the number of workforce is necessary.

Another solution focuses on training and development programs for personnel involved in changeovers. Through observations conducted on different personnel, it was determined that two workers changing the pulley of the shrink machine demonstrated faster completion times compared to others (Table 10, Appendix E). These findings indicate that the quickness of personnel directly impacts the duration of tasks. Therefore, it is recommended to assign faster workers to pulley changing to decrease downtime by approximately 65%.

To address the key problems identified in the changeover problem analysis, a combination of the Single-Minute Exchange of Die (SMED) methodology and the 5S methodology will be used.

The SMED methodology will be utilized to decrease the changeover time between different products in the aerosol line. By analysing the changeover process, it was identified that the preparation activities can be categorized as external activities, which can be performed while the machine is still running. The 5S methodology will be employed to optimize the preparation procedure.

The Sort step will involve removing unnecessary items from the production area, ensuring that only essential tools and materials that will be used in the changeover process are readily available. Set in Order will focus on arranging the necessary tools and equipment in a logical and ergonomic manner, minimizing the time wasted searching for items.

Shine will emphasize maintaining a clean and organized changeover area, preventing delays caused by clutter and obstructions, reducing the cleaning time during the changeover. Standardize will involve creating clear guidelines and standard operating procedures for the changeover process, ensuring that all the workers have a guide and do t waste time figuring out what should be done. Finally, Sustain will encourage the maintenance of the improvements made through regular audits and employee training, fostering a culture of continuous improvement.

Through parallelization of internal and external activities, the preparation time will be eliminated as a downtime component, resulting in a more efficient changeover process. The combination of the SMED and 5S methodologies will streamline the changeover process between products. After implementing these solutions, it was observed that the changeover time decreased from 15 minutes to 9 minutes, representing a significant reduction of 40% in changeover time (Table 11, Appendix E).

5.4. Production Failure Problem Analysis

Key Problem:

To identify the problems affecting the production failure in the aerosol line at EliteClean Innovations, a Root Cause Analysis (RCA) was conducted to delve into the underlying causes of the machine breakdowns, speed loss, small stops, and production failures in the water-bath machine. The RCA followed a systematic approach, involving a set of steps.

The initial step was to clearly define the problem, which included the low OEE and the specific issues observed in the water-bath machine. The focus was on understanding the root causes behind the abnormalities and their impact on machine performance. Relevant data, such as machine logs, maintenance records, and production reports, were gathered to analyze the historical performance and identify patterns or trends. This data provided valuable insights into the frequency, duration, and nature of the abnormalities.

After data gathering, the why analysis technique was used to dig deeper into the underlying causes of each identified factor. By repeatedly asking "Why?" and exploring the answers, the team aimed to reach the root cause of the problem. This helped to uncover the deteriorated chains, worn guides and star wheels, and poor plastic quality of the shrink as contributing factors. The questions that were asked are:

Table 4 Overview of asked questions

Why did the machine experience malfunctions?	Due to inadequate maintenance and lack of regular inspections.
Why did the machine have small stops?	Inconsistent power supply and improper lubrication of moving parts in the water-bath machine.
Why did the chains deteriorate?	Due to prolonged usage without proper lubrication and regular maintenance.
Why were the chains not properly maintained or replaced?	The lack of a scheduled maintenance plan and inadequate inventory management resulted in delayed chain replacements.
Why were the guides and star wheels worn?	They were subjected to excessive friction and wear due to prolonged operation without proper lubrication.
Why were they not regularly inspected or replaced?	The absence of a preventive maintenance program and insufficient monitoring led to overlooked inspections and delayed replacements.
Why did the containers drop during the process?	Due to misaligned guides and worn-out star wheels in the system.
Why was the plastic quality of the shrink subpar	Usage of low-quality materials from the supplier.

By repeatedly asking "Why?" and delving into the answers, the RCA process aims to uncover the underlying causes of the identified problem. This allowed for a more accurate understanding of the issues and provided a solid foundation for developing effective solutions to improve the performance of the aerosol line.

Key Solution:

To address the key problem identified through the Root Cause Analysis (RCA) of the production failures in the aerosol line at EliteClean Innovations, a series of steps were implemented. These steps focused on restoring the machine to its optimal condition, replacing key components, and implementing effective maintenance practices.

The first step taken was to restore the machine to its optimal condition. Skilled maintenance personnel were assigned to conduct thorough maintenance and repairs, addressing the identified issues such as inadequate maintenance, worn-out components, misalignment, and insufficient lubrication. Through meticulous inspection and adjustments, the machine was brought back to its optimal working state according to the provided brochure from the supplier.

To specifically address the identified issues with the water-bath machine, spare parts were ordered for the deteriorated chains, guides, and star wheels. These components were crucial for the smooth operation of the machine and had a direct impact on its performance.

In addition to the replacement of the deteriorated parts, the implementation of the TPM method was adopted. TPM focuses on maximizing machine efficiency and minimizing downtime through preventive and autonomous maintenance practices. Regular inspections, lubrication, and minor adjustments were carried out to prevent issues before they could lead to production failures. Special maintenance schedules will be issued for the ordered spare parts when they arrive. This approach will ensure the long-term reliability and optimal performance of the aerosol line.

Furthermore, the implementation of autonomous maintenance played a vital role in the solution strategy. Operators and line personnel were trained to perform basic maintenance tasks, such as cleaning, lubrication, and inspection, on a regular basis. This empowered the operators to take ownership of the machine's upkeep and reduced dependency on the maintenance team. By fostering a culture of proactive maintenance, the risk of malfunctions, speed loss, small stops, and production failures in the water-bath machine was decreased.

Through the combination of machine restoration, replacement of deteriorated chains, guides, and star wheels, TPM implementation, and autonomous maintenance, the key problem identified was successfully addressed.

Continuous monitoring and evaluation of the implemented solutions were put in place to ensure their effectiveness. Regular performance reviews, feedback collection, and data analysis were conducted to identify any recurring issues or emerging concerns, enabling proactive measures to be taken.

By implementing these comprehensive solutions, EliteClean Innovations not only resolved the identified problems but also established a robust maintenance and improvement framework for the aerosol line. This approach will contribute to the long-term efficiency, productivity, and success of the production process, ensuring smooth operations and minimizing production failures in the water-bath machine.

5.5. Results

In this section, the results of the implemented changes and improvements in the aerosol line's operational efficiency and OEE are presented. The data for the month of June was analyzed to evaluate the impact of the interventions on key performance indicators.

For the month of June, the total scheduled time for production in the aerosol line was recorded as 18,045 minutes. During this period, the total downtime amounted to 2,270 minutes. Calculating the availability factor, it is determined that the aerosol line achieved availability of (18045 - 2270) / 18045 * 100% = 87.41%. This represents a significant improvement compared to the previous period.

The productivity factor in the aerosol line increased from 95% to 96% after the implementation of the changes. This improvement indicates enhanced production efficiency and the utilization of available resources to maximize output. The quality factor remained at a consistent 100%, indicating that the implemented changes did not adversely affect product quality.

Combining the availability, productivity, and quality factors, the OEE for the aerosol line in the month of June was calculated as (87.41% * 96% * 100%) / 100% = 83.95%. This signifies a positive impact on the overall operational efficiency and performance of the line.

The improvements in the OEE can be attributed to the changes that were implemented in the aerosol line. Significant reductions in changeover time, speed loss time, and production failures were observed.. Although there were still some issues with the Water Bath machine due to delayed spare parts arrival, maintenance efforts were undertaken, leading to a significant reduction in the problem. These changes directly contributed to the increase in productivity and the overall effectiveness of the line.

Overall, the implemented changes had a positive impact on the aerosol line's performance, as evidenced by the increased OEE of 83.95% and improved productivity. The continued focus on optimizing the production process and addressing equipment-related challenges will further enhance operational efficiency and contribute to the achievement of the target OEE.

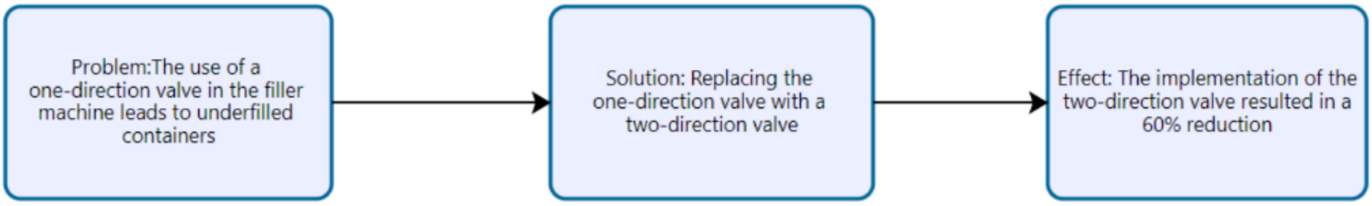

Figure 4 Problem-Solution-Effect Diagram for Speed Loss

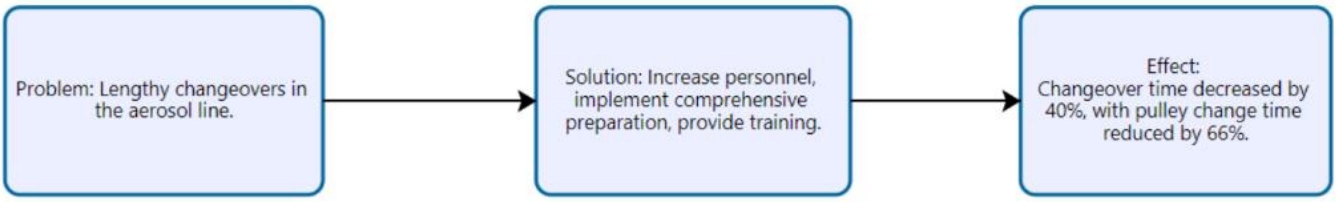

Figure 5 Problem-Solution-Effect Diagram for Changeovers

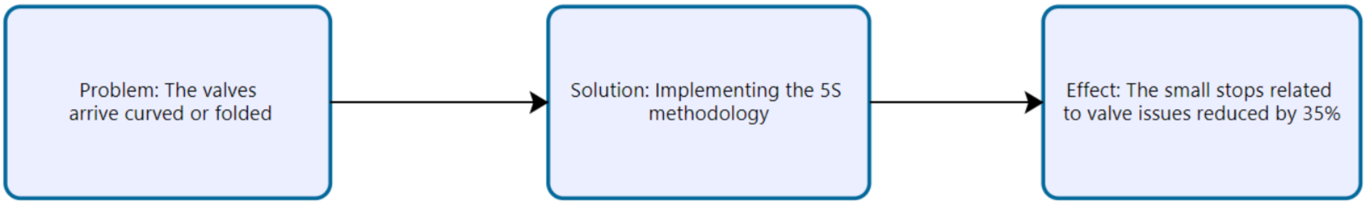

Figure 6 Problem-Solution-Effect Diagram for Small Stops

5.5.1. Costs

The analysis of changeovers in the aerosol line at the company revealed that, on average, there are around 20 changeovers per product per month. Through observations and the implementation of the SMED methodology, it was demonstrated that the changeover time can be reduced from 15 minutes to 9 minutes, resulting in a significant decrease of 6 minutes. With a performance factor of 96%, the aerosol line produces 192 products every minute. By reducing the changeover time by 6 minutes, an additional 1,152 products can be produced per changeover, totaling 23,040 more products in a month.

To quantify the financial impact of this efficiency improvement, the average profit per product was estimated at around 30 EGP. Consequently, the increase in production yields an additional profit of 691,200 EGP per month (23,040 products * 30 EGP). To facilitate comparison, the cost of adding an extra worker to the changeover process was calculated at 3,500 EGP per month. This cost includes the worker's salary and other related expenses.

The results indicate that the addition of an extra worker to the changeover process is a feasible solution. The enhanced efficiency and increased production throughput led to a substantial profit gain of 687,700 EGP per month (691,200 EGP - 3,500 EGP). The cost of the additional worker is offset by the significant increase in profits, resulting in a net gain for the company. Moreover, the improvement in OEE further contributes to the company's profitability and competitiveness in the market. All the values are indicated in the following table.

Table 5 Financial Impact of Changeover Time Reduction

Parameter	**Value (1 EUR = 34 EGP)**
Changeover Time (before optimization)	15 minutes
Changeover Time (after optimization)	9 minutes
Increase in Production per Changeover	1,152 products
Additional Monthly Production	23,040 products
Average Profit per Product	30 EGP (0.88 Euros)
Monthly Profit Increase	691,200 EGP (20329 Euros)
Cost of Extra Worker	3,500 EGP (103 Euros)
Net Monthly Gain	687,700 EGP (20226 Euros)

The results clearly demonstrate that optimizing changeover time through the application of the SMED methodology and adding an extra worker are highly effective strategies to increase OEE and maximize profits for the aerosol line at the company.

6. Conclusion and Discussion

This chapter will discuss the conclusions and the most important findings from the results of this paper.

6.1. Conclusion

The main goal of this thesis was to increase the OEE of EliteClean Innovations 's aerosol line by addressing the key bottlenecks affecting its efficiency and productivity. To achieve this goal, a comprehensive research approach was adopted, which facilitated the identification of critical issues and the proposal of effective solutions. The research question guiding this study was formulated as follows:

Research Question: What are the main bottlenecks affecting the OEE of the aerosol line in EliteClean Innovations , and how can they be addressed to achieve the target OEE of 85%?

To address the research question, several sub-research questions were formulated and answered:

Sub-Research Question 1: What are the specific reasons behind machine downtime in the aerosol line of EliteClean Innovations ?

Through data analysis and interviews, it was determined that the main reasons behind machine downtime were speed loss, production failures, small stops, and lengthy changeovers. Each of these factors significantly contributed to reducing the availability factor of the aerosol line and, consequently, its OEE.

Sub-Research Question 2: How does machine downtime impact the overall OEE of the aerosol line?

Machine downtime reduces the availability factor, which is one of the three factors of calculating OEE. If availability factor decreases, OEE decreases.

Sub-Research Question 3: What are the key factors influencing the changeover time in the aerosol line?

The analysis indicated that personnel efficiency, preparation, and the number of workers involved were critical factors influencing the changeover time.

Sub-Research Question 4: How can these bottlenecks be addressed to increase the OEE?

Speed loss was successfully decreased by replacing the existing one-direction valve with a two-direction valve. This change resulted in a significant decrease of 60% in speed loss.

Small stops solution was implementing rigorous inspections for incoming valves and providing a quality control process, the small stops related to valve problems decreased by 35%. However, small stops have the highest percentage of breakdowns after implementing the solutions.

Changeover was addressed by increasing the number of personnel assigned to changeovers, applying the 5S and SMED Methodology, and optimizing task allocation. These solutions, reduced changeover time by 40% and pulley change time by 66%.

Production failures, particularly related to the water-bath machine, were also identified as a significant bottleneck. Through machine restoration and temporary maintenance until the spare parts are received, the production failure rate decreased. By replacing deteriorated components, implementing Total Productive Maintenance and autonomous maintenance practices, the production failure rate will significantly decrease.

The implemented changes and improvements had a positive impact on the aerosol line's performance. The OEE for the month of June was calculated as 83.95%, representing a significant improvement compared to previous periods. The availability factor increased by 5.68%, and the productivity factor improved by 1%. However, the target OEE of 85% was not fully reached due to remaining challenges with the Water Bath machine and the limited availability of certain components.

To achieve the target OEE of 85%, it is crucial to address the remaining challenges and implement additional measures. Expedited delivery of the spare parts for the Water Bath machine is necessary to resolve the remaining issues and minimize downtime. Continuous monitoring and maintenance practices should be rigorously upheld to prevent any potential malfunctions or production failures.

In conclusion, by systematically addressing the research question and its sub-research questions, this thesis successfully identified and tackled the main bottlenecks affecting the OEE of EliteClean Innovations 's aerosol line. The implemented changes have resulted in significant improvements in the aerosol line's performance, as evidenced by the increased OEE of 83.95% and improved productivity. However, further efforts are needed to overcome the remaining challenges and achieve the target OEE of 85%. By addressing the remaining challenges, EliteClean Innovations can strive towards achieving the desired target OEE

6.2. Discussion

6.2.1. Implications and Contributions

Despite the limitations encountered during the research project, valuable insights have been gained that hold specific implications for both theory and practice, addressing the research question of improving the OEE of the aerosol line in EliteClean Innovations.

From a theoretical perspective, this research contributes to the body of knowledge on OEE improvement in the context of aerosol manufacturing. The identified bottlenecks, namely speed loss, lengthy changeovers, and production failures, have been analyzed in-depth, providing a detailed understanding of their impact on OEE. Additionally, the proposed solutions, such as implementing the two-direction valve, optimizing changeover processes, and adopting Total Productive Maintenance, offer practical methodologies tailored to EliteClean Innovations' manufacturing operations. These insights can serve as a foundation for future research in similar contexts and industries.

From a practical standpoint, the research outcomes hold direct implications for EliteClean Innovations and its aerosol line. By addressing the specific bottlenecks identified in this study, the management can take targeted actions to improve OEE and enhance operational performance. The implementation of the proposed solutions, such as the replacement of the one-direction valve and comprehensive preparation for changeovers, showed that it can lead to an increase in the OEE of the aerosol line.

By achieving an improved OEE, EliteClean Innovations can experience several benefits that align with its organizational goals. Firstly, the decrease in machine downtime and optimized production processes will result in reduced operational costs. The efficient use of production time and resources will lead to higher productivity and output without compromising quality. Moreover, the implementation of these solutions will contribute to the company's sustainability measures. With reduced downtime and increased efficiency, the machines will consume less electricity and resources, aligning with the company's commitment to environmental responsibility.

Furthermore, the research project has managerial implications for EliteClean Innovations. It highlights the significance of adopting a proactive approach to continuous improvement. By regularly assessing the machine and having a solid maintenance strategy, the company can optimize and enhace the performance of their machines, which will increase the OEE. The lessons learned from this research, especially the importance of timely spare parts management and proactive maintenance practices, can guide future decision-making and resource allocation for the company.

In conclusion, while the research faced limitations, the insights gained have practical significance for enhancing OEE in EliteClean Innovations 's aerosol line. The tailored solutions to address the identified bottlenecks, combined with a proactive approach to continuous improvement, offer concrete pathways to achieve the target OEE of 85%. By leveraging these implications, EliteClean Innovations can enhance its operational efficiency, increase productivity, and achieve its strategic goals in the competitive aerosol manufacturing industry.

6.2.2. Limitations

Several limitations were encountered during the research project that should be taken into consideration. Firstly, the research was conducted within a relatively short duration of approximately 10 weeks. This time constraint limited the depth and extent of data analysis and implementation of the proposed solutions. A longer timeframe would have allowed for a more comprehensive study and evaluation of the effectiveness of the implemented changes.

Observations of the aerosol line operations were also challenging due to the low number of personnel available for data collection. Limited personnel made it difficult to capture a complete picture of the operations and potential bottlenecks. The workforce was focused on their tasks, limiting their availability for extensive interviews and observations. This constraint impacted the richness and depth of the data collected.

Another limitation relates to resource availability. Due to external factors, such as issues with imports in Egypt as a result of government problems, the spare parts required for addressing the identified bottlenecks did not arrive during the duration of the internship. This limitation hindered the ability to fully implement and assess the impact of certain solutions on the OEE.

Furthermore, access to data regarding costs and allowances paid to the workers was restricted. As a result, a comprehensive cost-benefit analysis regarding the addition of workers to improve efficiency could not be conducted. The company will need to undertake this analysis separately to evaluate the financial implications of potential workforce adjustments.

Lastly, the research was focused specifically on the aerosol line of EliteClean Innovations. While this narrowed scope allowed for a more detailed analysis, it limits the generalizability of the findings to other manufacturing contexts. Different manufacturing processes or industries may have unique challenges and bottlenecks that require tailored solutions.

6.3. Recommendations

6.3.1. Result-Based Recommendation

Based on the identified solutions to address the issues in the aerosol line at EliteClean Innovations, the following recommendations are provided to optimize the OEE and ensure efficient production:

1. Speed Loss:
    - Establish regular monitoring and maintenance of the valves to sustain the improvements and prevent any issues that could impact production speed and accuracy.
    - Define and track performance metrics related to weight-filling accuracy to ensure consistent achievement of desired weight targets.
2. Small Stops:
    - Enhance the valve inspection and quality control process for incoming valves. Collaborate closely with the valve supplier to improve packaging and transportation methods, ensuring valves are received in optimal condition.
    - Establish clear quality standards and expectations with the valve supplier to maintain a high level of quality control.
    - Implement real-time monitoring of valve performance during production to detect deviations or anomalies and take proactive measures to address potential issues.
    - Establish a feedback loop with personnel to encourage reporting of valve-related problems and gather insights for ongoing improvement efforts.
3. Changeover:
    - Assign two people to be responsible for changeovers to divide tasks and work simultaneously, reducing changeover time.
    - Implement a comprehensive preparation process before changeovers, including the availability of cleaning and sanitizing tools, clear instructions, and timetables to minimize unnecessary delays.
    - Provide training and development programs for personnel involved in changeovers to improve proficiency and experience in specific tasks.
    - Standardize changeover procedures based on best practices and lessons learned to ensure consistent and accurate execution of tasks.
    - Assign the fastest workers to change the pulley of the Shrink Machine.

4. Production Failure:

    - Restore the machine to its optimal condition by conducting thorough maintenance and repairs, addressing issues such as inadequate maintenance, worn-out components, misalignment, and insufficient lubrication.
    - Implement Total Productive Maintenance (TPM) practices, including regular inspections, lubrication, and minor adjustments,especially to the replaced key components, to prevent issues and maximize machine efficiency.
    - Train operators and line personnel to perform basic maintenance tasks through autonomous maintenance, empowering them to take ownership of machine upkeep and reduce dependency on the maintenance team.

These recommendations, when implemented in a systematic and proactive manner, will contribute to the optimization of the aerosol line's efficiency, productivity, and overall equipment effectiveness. Regular monitoring, evaluation, and adjustment of the implemented strategies will be essential to maintain and enhance the performance of the aerosol line operations.

Table 6 Key Problem – key Solution- Key recommendation

	Key Problem	**Key Solution**	**Key Recommendation**
Speed Loss	The one-direction valve lacks precision, leading to underfilled aerosol products.	Replace the one-direction valve with two-direction	Ensure regular maintenance and tracking of filling accuracy.
Small Stops	Issues with valves arriving curved or folded, causing misalignment or malfunctions.	Implement 5S methodology for valve handling	Enhance valve inspection and quality control with the supplier. Establish real-time monitoring and feedback loop for valve performance.
Changeover	Low number of personnel assigned to changeovers, lack of preparation, and inefficiencies.	Utilize SMED and 5S methodologies. Assign two personnel for changeovers	Train personnel and standardize changeover procedures. Assign the fastest workers for pulley change.
Production Failure	Machine breakdowns, inadequate maintenance, worn-out components, and lack of lubrication.	Conduct thorough maintenance and repairs	Evaluate alternative suppliers and implement regular maintenance program.

6.3.2. Further Recommendations

After thoroughly exploring recommendations based on practical solutions, it is important to consider additional insights gathered from literature reviews and extensive meetings and discussions with stakeholders. This section will focus on recommendations derived from a combination of academic research and valuable input from key stakeholders within the organization.

- Review and optimize the staffing levels to ensure adequate personnel are available to meet production demands.
- Consider cross-training personnel to enhance flexibility and reduce dependency on a limited number of individuals.
- Consider alternative suppliers or negotiate improved quality control measures with the existing supplier.
- Implement a regular maintenance program to ensure all parts receive proper care and attention.
- Evaluate the feasibility of upgrading or replacing old machines with newer models that offer improved reliability and efficiency.
- Improve lubrication practices and ensure consistent power supply to reduce small stops caused by minor equipment issues.
- Keep a close eye on the shrink machine, valve machine, and filler 1 machine, as they have the second, third, and fourth highest percentages of breakdowns in the aerosol line after the water bath machine.
- Prioritize maintenance activities based on the breakdown percentages of these machines to allocate resources effectively and address potential issues promptly.
- Consider changing the knife of the shrink machine as it can be a potential cause of inefficiencies and breakdowns.
- Communicate the financial impact of slow changeovers to operators and maintenance personnel.
- Continuously monitor and evaluate the implemented solutions, conduct performance reviews, collect feedback, and analyze data to identify recurring issues or emerging concerns, enabling proactive measures to be taken.

6.4. Further Research

While this thesis successfully addressed the identified bottlenecks and improved the overall equipment effectiveness of EliteClean Innovations 's aerosol line, there are several avenues for further research in this area. First, conducting a more extensive study with a longer timeframe and larger sample size could provide deeper insights into the efficiency improvement strategies and their long-term impact.

Another research could be exploring the integration of sustainability practices in the manufacturing process, which will align with EliteClean Innovations 's commitment to environmental responsibility and cost optimization. Investigating the impact of different manufacturing layouts, production sequences, and inventory management techniques on OEE could also provide valuable information for continuous improvement.

In conclusion, further research in this area would contribute to the advancement of knowledge in manufacturing efficiency and offer practical insights for improving OEE in aerosol production. The continuous pursuit of research and innovation in this field is essential for companies like EliteClean Innovations to maintain a competitive edge and achieve sustainable growth in the dynamic manufacturing landscape.

6.5. Practical Contribution

This thesis makes a practical contribution by offering actionable solutions to enhance the overall equipment effectiveness of EliteClean Innovations' aerosol line. By addressing bottlenecks such as speed loss, lengthy changeovers, small stops, and production failures, the proposed methodologies are tailored to EliteClean Innovations' operations. The implemented changes have demonstrated tangible benefits, including an increased OEE of 83.95% in June. These solutions can be applied in other manufacturing industries, promoting efficiency, profitability, and sustainability. Also, recommendations were provided to the managers to further improve the operational performance of the aerosol line.

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Appendix A

The following pie chart presents the breakdown percentages of factors affecting the Overall Equipment Effectiveness (OEE) of the aerosol line at EliteClean Innovations. The data used to create this chart was analyzed in Microsoft Excel and provides valuable insights into the relative impact of each factor on the OEE.

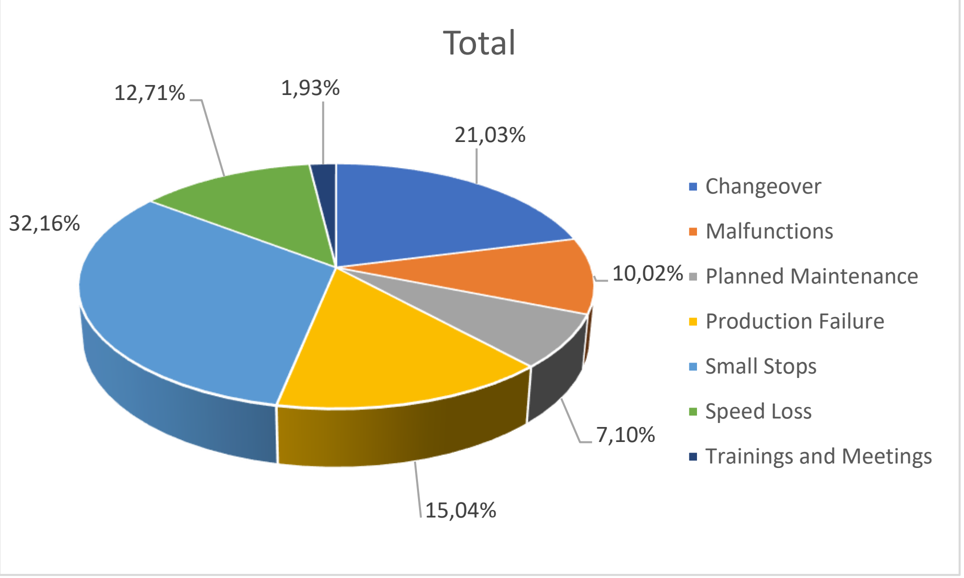

Figure 7 Breakdown of Factors Affecting OEE

The chart visually represents the distribution of the factors as follows:

Changeover: 21.03%

Malfunctions: 10.02%

Planned Maintenance: 7.10%

Production Failure: 15.04%

Small Stops: 32.16%

Speed Loss: 12.71%

Training and Meetings: 1.93%

This breakdown allows for a clear understanding of the significant factors contributing to the overall OEE performance of the aerosol line. By analyzing and addressing these factors, EliteClean Innovations can focus its efforts on improving specific areas to achieve the target OEE of 85%.

Appendix B

The following pie chart provides a breakdown of the machines with the highest breakdown percentages. The data used to create this chart was analyzed in Microsoft Excel, offering valuable insights into the relative impact of each machine on the OEE performance.

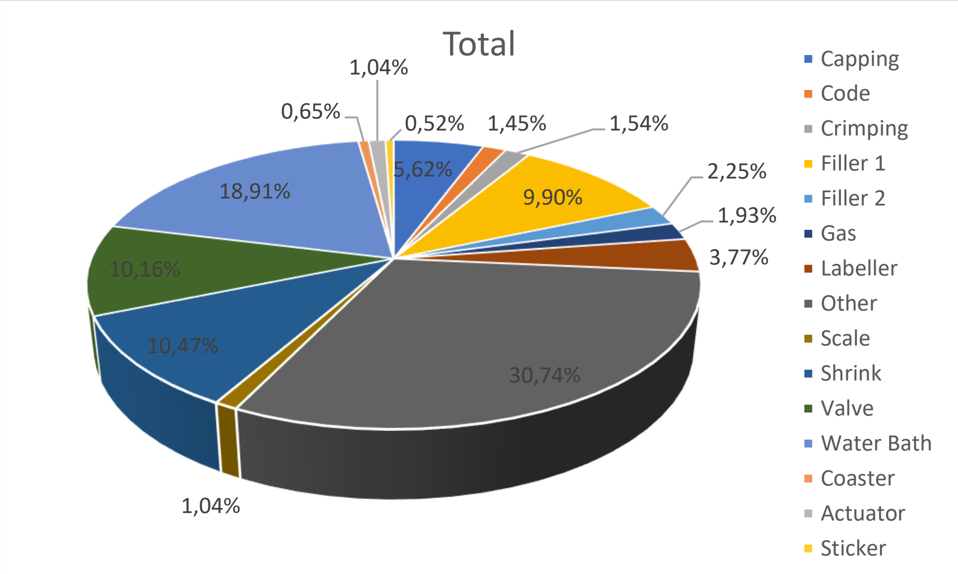

Figure 8 Breakdown Percentages per Machine

The chart illustrates the distribution of factors affecting OEE across the machines as follows:

Capping: 5.62%

Code: 1.45%

Crimping: 1.54%

Filler 1: 9.90%

Filler 2: 2.25%

Formula1: 0.00%

Gas: 1.93%

Labeler: 3.77%

Other: 30.74%

Scale: 1.04%

Shrink: 10.47%

Valve: 10.16%

Water Bath: 18.91%

Coaster: 0.65%

Actuator: 1.04%

Sticker: 0.52%

This breakdown provides a comprehensive view of the factors affecting the OEE performance for each machine in the aerosol line. By analyzing and addressing these specific machine-related factors, EliteClean Innovations can prioritize its efforts to optimize performance and improve the overall OEE of the aerosol line.

Appendix C

Problem-Solving Approach

Table 7 MPSM Stages

Stage 1	Defining the problem
Stage 2	Formulating the approach
Stage 3	Analyzing the problem
Stage 4	Formulating alternative solutions
Stage 5	Choosing a solution
Stage 6	Implementing the solution
Stage 7	Evaluating the solution

Table 8 Research Cycle Stages

Stage 1	Formulating the research goal
Stage 2	Formulating the problem statement
Stage 3	Formulating the research questions
Stage 4	Formulating the research design
Stage 5	Performing the operationalization
Stage 6	Performing the measurements and Gathering Data
Stage 7	Processing the data gathered
Stage 8	Drawing conclusions

Appendix D

Interviews

Introduction

First I will state my name and state that I am conducting this interview as part of my thesis research. I would like to thank you for taking the time to participate. I will then talk about the purpose of the interview and state that their expertise and perspective will greatly contribute to my research.

Before we start, I will assure them that their participation is completely voluntary, and their responses will remain confidential. I will state that the answers provided will be used solely for academic purposes and will not be shared with any third parties.

Questions

1. Please introduce yourself and briefly describe your role and responsibilities within the aerosol line at EliteClean Innovations.
2. How long have you been in this role, and what is your experience in dealing with OEE-related challenges?
3. In your opinion, what are the main factors or bottlenecks that significantly affect the OEE of the aerosol line?
4. Can you provide specific examples or instances where you have observed these bottlenecks causing disruptions or inefficiencies in the production process?
5. What do you think are the underlying root causes of these bottlenecks affecting the OEE of the aerosol line?
6. Based on your experience and knowledge, what potential solutions or strategies do you believe can address the identified bottlenecks and improve the OEE of the aerosol line?
7. Are there any specific areas where you believe improved collaboration or coordination among team members would be beneficial for OEE enhancement?

Conclusion

I will conclude the interview by thanking them for sharing their insights insights and experiences. To ensure accuracy and maintain transparency, I will provide the interviewees with a copy of their responses for review and verification. I will state that If they would like to make any changes or if there is any information they feel should not be published, they have to let me know, and I will accommodate their requests. I will state that their name and any sensitive details will be removed or anonymized in the final thesis and any related publications. I will thank them again and state that if they have any further questions or concerns they shouldn't hesitate to contact me.

Appendix E

Observations

The observation section of this thesis is specifically focused on analyzing the changeover process within the aerosol line. This decision is based on the availability of comprehensive data provided by the company, which already includes records and comments for other breakdowns along with explicit reasons for the stops. Therefore, the observation effort will be dedicated exclusively to studying the changeover process, with particular attention given to two critical aspects: the time required to change the pulley of the shrink machine and the duration of transitioning between different products.

The main reason for conducting these observations stems from the surprising finding in the data provided by the company. Specifically, the data indicated that the changeover of the pulley of the shrink machine took a full minute, which appeared unusually long for what was perceived as a relatively simple task that does not require high skill levels but rather efficient execution and speed. This revelation prompted the need for direct observations to better understand the inefficiency and identify potential areas for time reduction.

Similarly, the 15-minute duration recorded for the changeover between products also raised concerns regarding potential areas for improvement. By closely observing this process, the aim is to identify any bottlenecks, unnecessary steps, or other factors contributing to the prolonged changeover time. Through these observations, practical solutions can be developed to streamline the changeover operations and decrease downtime between product transitions.

By meticulously observing and tracking the time during these changeover events, valuable insights can be gained to assess whether there are opportunities for decreasing changeover times and optimizing the operational flow. Additionally, engaging with the personnel involved in the changeover process will provide valuable perspectives and experiences, contributing to a comprehensive analysis and forming a basis for effective recommendations to enhance changeover efficiency and overall operational performance of the aerosol line.

Products Changeover

The purpose of this observation is to examine the changeover process from one product to another in the aerosol line. According to the data provided by the company, the changeover process currently takes approximately 15 minutes. However, it is believed that there is potential to decrease this time. Therefore, the observation aims to gain a detailed understanding of the changeover procedure and identify opportunities for reducing the overall duration.

Due to the lengthy nature of the changeover process and the production schedule designed to minimize changeovers, four observations were conducted on different days. Two observations were performed while only one person handled the changeover process, and the other two observations involved two individuals working together to complete the changeover.

The changeover process involves several steps, which include preparation, clearing residual products, cleaning the equipment and machine, sanitizing the entire line and workspace, and adjusting the machine settings to accommodate the new product.

Table 9 Observations with 1 person conducting the changeover process

Observation	Preparation (mm:ss)	Clearing Residual Products (mm:ss)	Cleaning and Sanitization (mm:ss)	Adjusting Machine Settings (mm:ss)	Total Duration (mm:ss)
1	02:12	04:37	06:40	01:29	14:58
2	02:47	04:22	06:14	01:50	15:13

Table 10 Observations with 2 persons conducting the changeover process

Observation	Preparation (mm:ss)	Clearing Residual Products (mm:ss)	Cleaning and Sanitization (mm:ss)	Adjusting Machine Settings (mm:ss)	Total Duration (mm:ss)
1	01:08	03:46	04:42	00:52	10:28
2	01:32	03:27	04:52	00:55	10:46

From the observations, it can be seen that the changeover process takes approximately around 15 minutes when conducted by a single person. The cleaning and sanitization component varies between 06:14 to 06:40, making it the most time-consuming step. The preparation and adjusting machine settings steps also contribute to the overall duration.

When two persons work together, the changeover process can be completed in approximately around 10 minutes. In this case, the clearing of residual products, cleaning and sanitization, and adjusting machine settings are more efficiently distributed between the two individuals.

Table 11 Observation with the SMED method and 2 persons conducting the changeover process

Observation	Preperation (mm:ss)	Clearing Residual Products (mm:ss)	Cleaning and Sanitization (mm:ss)	Adjusting Machine Settings (mm:ss)	Total Duration (mm:ss)
1	00:00	03:36	04:27	00:52	08:55
2	00:00	03:20	04:55	00:55	9:10

In this observation, the changeover process from one product to another in the aerosol line was conducted using SMED methodology. The goal was to decrease the changeover time by eliminating the need for preparation, which was considered an external activity that can be performed while the machine is running.

In this observation, it can be seen that by separating the external activity of preparation, the changeover time was reduced to approximately 9 minutes. The steps of clearing residual products, cleaning and sanitization, and adjusting machine settings were still performed, but without the need for dedicated time for preparation.

Changing the Pulley of the Shrink Machine

The following table presents the observations of the time taken by different personnel working on the aerosol line to change the pulley of the shrink machine. The observations were conducted three times per person, focusing on their efficiency in completing the task. It is important to note that Worker 1 and Worker 2 exhibited consistent performance, while Workers 3, 4, and 5 demonstrated slower but relatively consistent completion times, taking approximately 38 seconds to change the pulley. Worker 6 and Worker 7, due to their age, took longer, averaging around 1 minute to complete the task.

Table 12 Time Taken to Change Pulley of the Shrink Machine (in seconds)

Worker	Observation 1	Observation 2	Observation 3
Worker 1	18	20	20
Worker 2	20	19	21
Worker 3	35	40	36
Worker 4	39	37	41
Worker 5	37	36	40
Worker 6	60	61	58
Worker 7	58	63	60

The time taken to change the pulley of the shrink machine revealed variations in performance among the workers. Worker 1 and Worker 2 consistently demonstrated the fastest completion times, with an average of approximately 19.33 seconds. Workers 3, 4, and 5, despite taking longer at around 38 seconds, displayed relatively consistent performance in completing the task. Worker 6 and Worker 7, due to their age, exhibited slower performance, averaging approximately 60 seconds (1 minute) to complete the pulley change.

The observations highlight the importance of quickness in completing the pulley change task. Worker 1 and Worker 2, being the fastest and most efficient, can significantly contribute to minimizing machine downtime associated with pulley changes. Their combined efficiency accounts for a substantial portion of the total observed time. While Workers 3, 4, and 5 take longer to complete the task, their relatively consistent performance suggests that they can still contribute effectively. However, the slower completion times of Worker 6 and Worker 7, due to their age, indicate the potential impact of quickness on task efficiency.

To optimize production efficiency and reduce breakdowns related to pulley replacement, it is crucial to consider the quickness of workers when assigning them to this task. Prioritizing the faster workers, such as Worker 1 and Worker 2, while still considering the relatively consistent performance of Workers 3, 4, and 5, can help minimize machine downtime and enhance overall productivity. Quickness in completing the pulley change task is a significant factor in maintaining smooth operations on the aerosol line.