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Implementation of 5S Management in Battery Industry: A Case Study

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Abstract

Over the last few years, the rapid growth and vigorous development of the lithium-ion battery industry is obvious. The overall production and market scale of global lithium-ion batteries have grown rapidly, and the technology has become more mature, mainly due to the rise of emerging markets such as smartphones, tablet computers, and electric vehicles, which have promoted technological progress and market prosperity of the lithium-ion battery industry.

This topic is focused on the implementation of the 5S methodology on the production site of the Norwegian battery company Beyonder AS, which is a start-up company that needs a scientific way of managing its site condition as well as employee awareness of the workplace.

The purpose of this thesis is to implement 5S management in a battery company to gradually obtain the 5S results, which will gradually promote Beyond to have a 5S structure that can be applied on-site and in later mass production.

During this research, it will preliminarily establish a model based on 5S as a foundation for TPM later, and in line with Beyonder manager for the purpose of improving operation quality. It also improves the on-site work environment, improve the stability of the performance of operator, and reduce the equipment failure rate, and Improve the ability of employees to find problems and laid a good foundation for other management methodology.

The general research methodology is the PDCA cycle combines with the 5S application. After literature review and case analysis, problems on the production site are listed, then follow the 5S procedures, gradually improve the condition of the production site. In the meantime, evaluation chart and sheet have been used for weekly checking and Analytic hierarchy process, which act as the Check phase of the PDCA cycle for proposing further improvement.

After the implementation, problems regarding the topic were solved, the company are satisfied with the result. Studies have shown that 5S management can greatly improve the working environment for enterprises, set the mindset of 5S for employees, and create an organized environment for operators. It directly lowered the short circuit number of batteries, especially during the stacking process. Moreover, this thesis laid the solid foundation for production sites' further improvement. The scientific value of this research is that several proposed methods were shown practical and useful for 5S implementation in the battery industry.

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This research was developed from winter 2020 to summer 2021 for my degree of Master of Science (MSc) in Offshore Technology with a major in Industrial Asset Management. This study has been fun, and I experienced a lot. The topic was also interesting, which let me explore all aspects of the battery industry, from supply chain to production process, machine set-up and battery quality testing. The knowledge from the literature review and weekly master thesis meeting really helped me during this research.

I want to thank Professor Idriss El-Thalji, my supervisor for this research, for his great help in writing the thesis and guided me in scientific writing. I really appreciate that he offered his help and patient to me.

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1. Introduction

1.1 Background

The research focused on the implementation of 5S management in the new production line of a battery cell company. By combing theories from the state of the art articles with a deep understanding of problems and current condition, propose a more practical way, which could be appliable on larger scale production later, to manage the production site, then implement it and evaluate the result after application. This research also gives a background description of the big picture of the power battery industry.

In the global battery industry, the rapid growth and vigorous development of the lithium-ion battery industry is obvious. In recent years, the overall production and market scale of global lithium-ion batteries has grown rapidly, and the technology has become more mature, mainly due to the rise of emerging markets such as smartphones, tablet computers, and electric vehicles, which have promoted the technological progress and market prosperity of the lithium-ion battery industry.

The key characteristics of lithium-ion batteries over other products include easy availability, high energy density, low discharge rate and prolong life cycle.
Lithium-ion batteries are the core components of electric vehicles, and they have also become the leading components in major application markets such as mobile devices and grid energy storage. For a long time, many countries have listed electric vehicles as their main target. The United States has supported many national laboratories and companies to undertake the development of lithium-ion batteries for vehicles. The European Union has formulated a development plan for high specific energy batteries. Japan has a monopoly in the field of lithium-ion batteries. Famous companies such as Sony, Sanyo Electric, Matsushita Battery, NEC and others have built large-scale lithium-ion battery production plants.

In 2019, the installed capacity of power batteries was approximately 115.21GWh, a year-on-year increase of 22%. In 2020, the installed capacity of power batteries was approximately 137GWh, a year-on-year increase of 17%.

Due to the high technology, capital and experience required for power battery production and R&D, and the market concentration is increasing. The total installed capacity of the top ten power companies in 2019 is about 102.4GWh, accounting for 89% of the global installed capacity of power

batteries. The total installed capacity of the top ten power companies in the first three quarters of 2020 is about 72.01GWh, accounting for 93% of the global power battery installed capacity, and the Matthew effect in the battery industry is becoming more and more obvious. To be competitive in the business, companies in the battery industry need to deliver their product with better quality, lower prices and higher customer satisfaction level, or in term of competition theory, they need either add more value to their product or compete in a lower price. Therefore, how to survive the competition and gain profit are always rank the top priorities of managers of the case company. The thesis analysis the problems and study the theories and provide guidance for implementing 5S methodology.

1.2 Problem definition

This research focuses on implementing 5S in a start-up company that is in the emerging lithium-ion battery industry, analyzing the existing problems on site. The equipment in the production line is new and have different requirements for the user, and there is no clear work about on-site management. Engineers and technicians from all over the world hold different working standards in the production site. As a company in its early stage, managers have not done all the on-site management standard and operation manual for each process, and the production site was unorganized. Some workers are learning by working, and lack of system training, which might cause unwanted lose in production.

Also, although the 5S has been studied for a long time as well as its elements, for several reasons, little research can be found for specific 5S implementation steps for the battery industry (Lamprea et al. 2015), so trying to fill the gap between reality and theory in implementation is also a problem to be solved.

1.3 Research objectives and general approaches

The problems above result in thesis research objectives, the successful implementation of the elements of TPM: 5S in the new production line. More specifically, the objective of the 5S program is trying to figure out two objects, firstly, what needs to be done to fulfil 5S in the battery industry, secondly, how to do it in practice, as the production site need to satisfy strict requirements due to the characteristics of battery cell production line.

Below are the general research approaches that been used in this study. The research methodology chapter is formed gradually based on those general approaches as a guideline.

1. Literature research method: According to the problems faced by the Beyonder factory,

consult relevant monographs, articles, fully grasp the theoretical knowledge of 5S management and provide theoretical support for the subject research.

2. Data statistical analysis method: statistical analysis of quality operation data, analysis of the corresponding changes in production data, to provide data support for subject research.
3. Experience summary method: summarize and analyze the current status and existing problems of the implementation of 5S management of Beyonder, summarize and analyze the effective improvements that have been taken and the experience gained, and formulate improvement plans for the subject research.
4. Interdisciplinary research method: refer to the theories, methods and achievements of human resource management, organizational behaviors, social psychology and other multi-disciplinary research 5S management personnel training and team building.

1.4 Significance of the Subject

Beyonder's on-site management was in its early stages. This paper will improve on-site management by studying the current management methodology based on Beyonder's current site and production management mode to obtain the 5S results gradually. It empowered Beyonder to have a 5S structure that can be applied on-site and in later mass production.

During this research, it will preliminarily establish a model based on 5S, as a foundation of Total Productive Maintenance later, and in line with the Beyonder manager for the purpose of improving operation quality. It also improves the on-site work environment, improves the stability of the performance of the operator, and reduce the equipment failure rate. The ability of employees to find problems has enhanced a good foundation for other management methodology. And the plan for this research is shown below.

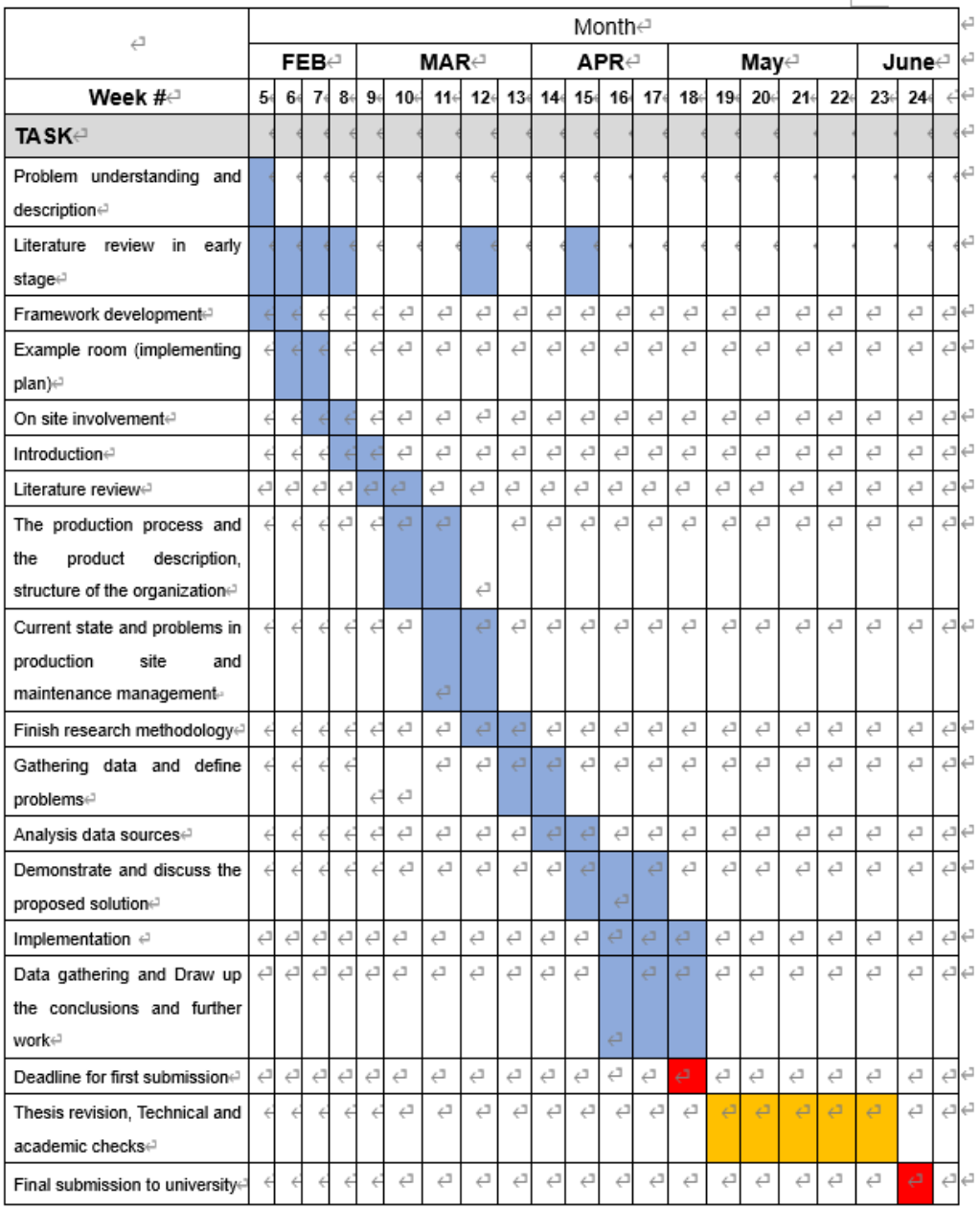

Figure 1. Plan for research

By implementing 5S, companies can often avoid various accidents and failures caused by non-compliance with safety rules, or pollution caused by dust or oil pollution, etc. Therefore, production safety can be implemented. 5S can achieve a clean, tidy, safe and comfortable environment and a well-qualified workforce, which can often win the trust of customers.

Through the implementation of 5S, the habit of observing standards is cultivated within the enterprise so that all activities and operations are run according to the standard requirements. The results are in line with the planned arrangement, laying the foundation for providing stable quality. Dust, fiber, oil and other impurities often reduce the processing precision and even directly affect the quality of the product. After the implementation of 5S, cleaning and cleaning is guaranteed.

Products are formed, stored, and delivered to customers in a good hygienic environment, and the quality is stable. Through the implementation of 5S, the loss time in production is reduced, and work efficiency is improved. Also, the failure rate of equipment is reduced, and the efficiency of equipment use is improved, thereby reducing certain production costs.

1.5 Structure of the work

The following is the main content of the chapters of this article, as the figure shown below.

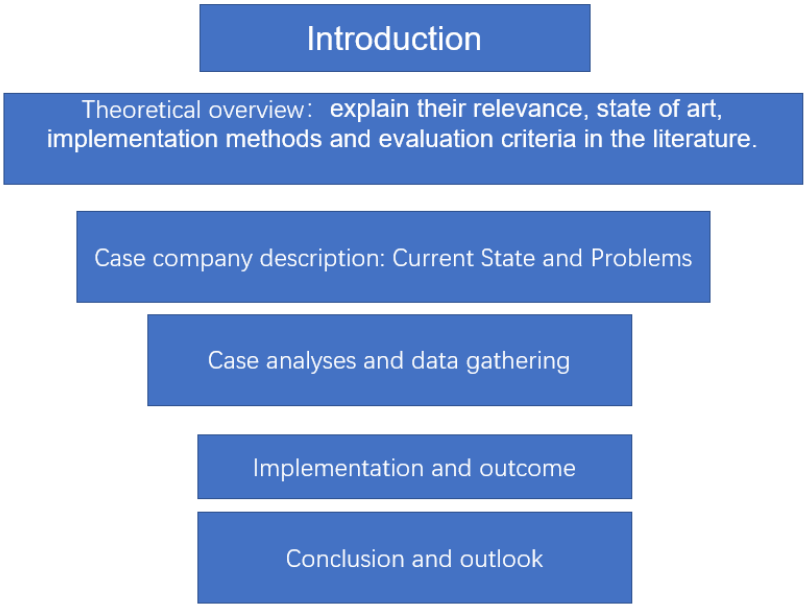

Figure 2. Structure of the work

It begins with Chapter 1, an Introduction, which depicts the current status of the lithium battery industry, and the need to improve. This part also gives a brief description of 5S, explain research problems, objectives, and research approaches and the significance of the subject.

Chapter 2 is the Literature review. A theoretical overview of 5S site management, about the application, the topic and the used methods, then separately explain the content and meaning, explain their relevance, state of the art, implementation methods and evaluation criteria in the literature.

Chapter 3 will be the case description of this battery cell manufacturer, which involves the production process and the product description, structure of the organization. It highlights the production site current state and the problems that been found during this research. Thus put forward the necessity of the implementation of the 5S methodology.

Chapter 4 is about the methodology part of this research. This chapter presents the proposed research design that is required to answer the research question, achieve the research goals and test the research hypothesis. The proposed research design covers all steps that shall be performed and determine the data sources and collection and analysis methods.

Chapter 5 is the start of implementation, based on the method theory which has been proposed, and what is needed to improve in the production site in practical, follow the plan and use the PDCA methodology, improve company performance in the aspect of 5S, use the analysis method that been used earlier to evaluate the site performance again, as the 3rd step of PDCA cycle, check what has been achieved, and show some of the results.

Chapter 6 is to finalize the research and discuss what needs to be improved and summarize the achievement that been done by the 5S team of Beyonder, point out the key points in practical implementation, to fill the gap that few 5S implementation related research can be found of battery industry, as an contribution to other's scientific research.

To sum up, based on Beyonder's practice, make a corresponding summary, and modify the deficiencies, laying a good foundation for the company's development in the next step. This article analyzes the basic situation of the company on-site management, combines the theoretical knowledge and sketches the implementation content, and carry out the practice and analyze the problems based on the research results.

2. Theoretical background

2.1 5S management methodology

5S was originated in Japan, which is one of the techniques that enabled Just in Time manufacturing and Total Productive Maintenance management.

5S is a lean management technology that is used to deal with the work environment, that is, Sorting, Shining, Set in order, Standardization, and Sustain. Everything ends with the improvement of the work process. 5S is a quality technology that can help reduce waste, reduce time, and increase productivity (Aman et al., 2019).

In the early 1950s, proposals said that sorting and setting items would support overall performance and safe production. As the need for quality control, companies in Japan started to focus on the accomplishment of workers, so to make the 5S management was more practical and flexible to different kinds of industries. Based on the 5S management, Japanese enterprises put forward a series of management methodologies and attention was on the quality of service and product. One of the reasons why Japan became a powerful country is the attention paid to the 5S methodology, which contributed to the improvement of quality management.

2.1.1 The concept of 5S site management system

Japan has developed 5S management, which aims to develop good working habits by applying standards in the workplace and material management to establish a comfortable and clean working environment. With the rise of Japanese manufacturing, 5S management has spread to every corner of the world. 5S consists of 5 Japanese terms (Seiri, Seiton, Seiso, Seiketsu, and Shitsuke) used in many industries, especially manufacturing and service industries.

What's more, due to the requirements of further development of enterprises, some enterprises have adjusted their original 5S management according to their needs.

For example, some companies have added Safety to 5S, and some have added Save, Shiukanka, Service and even Shikoku to their original companies to meet their specific needs. Therefore, the basic idea of the above management method remains unchanged: to improve the enterprise's management system and produce high-quality goods and services.

Next, the content of 5S management will be introduced in detail.

1) The concept of SEIRI (Sort)

To improve the production area, the first thing to do is to distinguish between what is needed and what is not needed. After a clear distinction, removing unnecessary items and handling them properly can eliminate obstacles and make work easier. Usually, excess items, such as remaining

raw materials and products, need to be modified or returned to the workplace. 5S advocators believe that placing unnecessary items in the production area is a burden for the company.

Unused tools, modes, and outdated machinery and equipment in the workplace make it difficult for workers to find what they need as quickly as possible. Under the occupation of these things, shelves and cabinets were more and more crowded. The disorderly placement of items also aggravated the narrowness of the original space. Therefore, evaluating necessary items related to cost or other related factors and defining areas with red tags to keep unnecessary items will be a better way for companies to get the start for 5S.

2) The concept of S2 SEITON (set in order)

Seiton in Japanese means to arrange items systematically and can also be translated as "Set in Order" or "Streamline.". It refers to arranging all necessary items so that they can be easily selected for usage, which is the basis for improving efficiency. Based on the first step, remove unnecessary items from the workplace, so the necessary items need to be placed in order. Therefore, principles need to be determined to ensure that each item reaches the desired location. The systematic arrangement of necessary items prevents waste and time wastage and aims to create a smooth and relaxed workflow.

3) The concept of S3 SEISO (Shine)

Seiso in Japanese means cleaning the workplace thoroughly to make the workplace comfortable and easy to work and prevent damage to machinery and equipment due to a dirty environment. It can also be translated as "clean". Therefore, a responsible area should be constructed to investigate the source of pollution and clean the environment. Basic standards should also be established so that basic order and a clean workplace can be maintained accordingly.

4) The concept of S4 SEIKETSU (standardized)

Based on the previous steps, the manager or owner of the company should set a typical example in the workplace so that other employees can learn from best practices. Seiketsu requires all procedures that been formed from the previous 3S can be settled and documented as standard. In order to maintain a high standard of order and workplace organization, Seiketsu requested to create a comfortable working environment.

5) The first four steps of the 5S SHITSUKE (Sustain) concept of on-site management are easy to implement, but whether workers can perform these steps for a long time still needs to be persistent. Shitsuke means sustainable development. The necessary training and discipline can help perform the 5S steps, but managers still need to get feedback from workers so that they can adjust specific rules based on actual conditions.

2.1.2 The internal relationship of 5S management

The five aspects of 5S management cannot play an effective role alone. When they are closely linked together as a system, they can help enterprises solve the problem of the dynamic work environment. The first four elements are carried out by employees in their daily work and influence the development of the concept of sustainability. All in all, the five aspects can work to establish the work in progress and maintain the improved activities in a more comfortable and safer workplace. (Filip et al., 2015).

2.1.3 The significance of 5S management

Even if a company has the most advanced production technology or the latest equipment, it will never succeed without effective management. If there is no effective management, the worksite will be chaotic. The accessories will be placed in a disorderly manner, which leads to a reduction in employee activities and ultimately a reduction in production efficiency. The 5S on-site management methodology can effectively solve the problem of low on-site management efficiency and lay a solid foundation for further improving the working environment and achieving success.

The abbreviation of five Japanese characters, 5S, can improve enterprises' working environment and increase productivity and product quality. At the same time, it also helps to encourage employee activities followed by other management activities. The significance of 5S management can be realized from the following perspectives.

First, it improves the quality of the company's products. Generally speaking, different processes may be running at the same time during the production process. If there are any problems with the equipment or planned procedures, conflicts will occur, so the related products will be affected in the process. Through strict control of quality management, the implementation of 5S management can effectively solve the problem. By establishing a detailed and strict quality management system, 5S management can enhance the overall monitoring of material procurement, production process and logistics, thereby increasing the qualification rate and avoiding conflicts.

Second, it reduces the possibility of accidents. In order to reduce the possibility of safety accidents, 5S management methods should be used cautiously. The most important part of 5S management is to execute the first three processes effectively and last for a long time. It means to sort, arrange, and clean the system to locate different kinds of items and equipment and ensure that the work site's passage should be unobstructed and do not place unnecessary items or equipment in inappropriate places. Ensuring everything is in order and being organized is a basic aspect of reducing the possibility of accidents, so the safety of employees can be guaranteed.

Third, it helps to reduce waste and cost. On the one hand, it helps organize idle materials or items in the process of 5S management. It can also clean old materials that have been too long in stock. Also, waste materials can be recycled to reduce waste. At the same time, the implementation of 5S management will also help reduce environmental pollution.
On the other hand, the project cycle can also be shortened. By implementing the 5S management method and carefully implementing each step, the company can understand the management conditions at a glance. Abnormalities could be presented, unnecessary waste of human resource, equipment, time or energy.

Fourth, it helps to improve the performance of work. The focus of 5S management is to improve worker's performance by taking various actions to change the working environment. It can improve the classification, system arrangement and standardization, working environment of the first four steps, and at the same time improve the quality of operation. Through a period of steps, a sustainable habit of creating a pleasant working environment will be developed through a period of steps. People will feel satisfied when working in a comfortable environment, so it can also improve work efficiency and promote teamwork between different types of employees.
Last but not least, the implementation of 5S management helps to build a better corporate image. The purpose of implementing the 5S management method is to improve the working environment and maximize profits and plans to improve the overall image of the company. Encourage employees to develop good behavior and hard work habits through strict compliance with corporate regulations and standards. Because of the clean, orderly production process and high-quality work performance, the company can be easily trusted by the public and can produce high-quality goods or services. In this way, talents will be attracted by the company and achieve higher work performance.

2.1.4 Relationship with other management systems

As an important part of site management, 5S management has laid a solid foundation for total production maintenance (TPM) and total quality management (TQM), which is also very important for the implementation of ISO9000.
At the same time, due to the main role of 5S management, the relationship with other management systems can be compared. On the basis of 5S management, the main standards are established to enable employees to participate in the five steps of workplace management according to typical examples, thereby establishing a good work atmosphere. Therefore, other management activities (such as ISO, TQM and TPM) will be easier to win the support of employees. (Kareem et al. 2015).

Then all management systems can work together to provide a strong impetus for the development of the enterprise.

In addition, without the main foundation of the 5S management method, the implementation of other management systems is impossible. No matter what direction the company focuses on, having a solid foundation is always the top priority. Since the impact of TPM, TQM or ISO is implicit in the short term, it is difficult for employees to get timely feedback from the activities they initiate. However, the immediate effects of 5S management will encourage employees and can inspire great confidence to continue participating in activities.

2.2 Current status of on-site management

2.2.1 Status of research

5S originated in Japan and referred to the continuous implementation of five management procedures in the enterprise, including Shiri, Seiton, Seiso, Seiketsu and Shituke. The 5S management method has been widely used in Japanese manufacturing companies and later spread to other countries due to the rapid development of the Japanese economy. As a practical theory that generated daily production experience, the research on 5S management includes the impact on the enterprise and the relationship with other management methods.

At the beginning of the 20th century, Frederick Winslow Taylor, the father of scientific management, published "Principles of Scientific Management" based on his years of field management experience. After about 50 years of development, Japanese companies successfully implemented the first two 5S methodology plans in the manufacturing industry in 1955 to ensure production space and work safety. This method has been better improved during the expansion and further development of Japanese companies and was adapted to the 5S method in 1986.

In the 1960s, industrial engineering-related production management models continued to improve and develop, and production companies in the United States, Germany and other countries began to realize the importance of scientific production site management models.

In the middle and late 20th century, American automobile companies gradually began to introduce scientific on-site management methods. Among them, Ford Motor Company in the United States developed management ideas and introduced on-site management models. While continuously improving management and innovation, Ford established the first production line of the automobile company, which greatly improved the production efficiency of the enterprise, and provided valuable experience for future automobile assembly line production (Bemoan B M.1998).

Until the early 1990s, Dr. Michael Hammer of the United States conducted a more thorough analysis and research on corporate processes, combined with existing management models and corporate

processes, and worked out a process reengineering that was in line with corporate development. The scheme design has laid a good management foundation for the improvement of field management in the future.

The on-site management theory of enterprises has gradually formed a mature on-site management mode and system through continuous application and practice. At present, the management mode represented by the 5S on-site management theory of Japanese manufacturing enterprises is welcomed by many enterprises. Companies make reasonable innovations based on actual conditions and find a set of 5S on-site management models that are in line with the company's own development.

Literature review about 5S implementation method

A test study was conducted in 16 hospitals, and the waiting time of patients was reduced by implementing 5S tools (Ishijima, .2016). Before starting the study, they had conducted a baseline study in every 16 hospitals, and after the intervention, the reduction in average waiting time was compared with a different analysis to check the results of 5S. Studies have shown that the implementation of the 5S method has a positive effect on reducing the waiting time of patients. The study also shows that the use of 5S methods can shorten the delivery cycle of health services.

Oleghe Omogbai et al. (2016) introduced a case study using system dynamics to implement 5S in a printing and packaging manufacturing company. System dynamic modelling has been developed to solve problems such as demand fluctuations, system inefficiencies, failures and improper scheduling. They developed the governing equations for the system dynamics model and verified them through experiments. Research shows that with the improvement of 5S practice, the system dynamic model that has been developed has also been improved.

Dr. Anna Khan et al. (2017) explained the method of implementing 5S and concluded that 5S had brought positive changes to the organization, for example, reducing process costs, improving process efficiency and effectiveness, reducing pollution and improving Safety. The study revealed the general obstacles to the implementation of 5S. It takes about 3-4 months for any organization to implement 1S, 2S and 3S fully.

Kanban

Kanban was originally created by Toyota Motor Corporation in the 1950s from the operating mechanism of the supermarket as a transmission tool for production and delivery instructions. After nearly 50 years of development and improvement, it has played important functions in many aspects.
Record and display work information
Production and delivery of work orders are the most basic functions of Kanban. The company's production management department issues production orders based on the market to the general assembly line, and the production of each pre-process is carried out according to the Kanban. Kanban records the production and delivery quantity, time, destination, storage location, transportation tools and other information, which can be traced from the assembly process to the previous process step by step.

Kanban must be used in accordance with established operating rules. If there are no Kanban in each process, neither production nor delivery will be carried out, and if the number of Kanban is reduced, the production volume will be reduced accordingly. Since the Kanban indicates the necessary quantity, the use of the Kanban can automatically prevent overproduction and excessive delivery.

Visual management

With the help of observation, the abnormality can be found, which makes the problem, abnormality, waste, etc. in the workplace clear at a glance. (Tezel et al. 2016)
It is the specific reflection of the previous 3S. The latter 2S is needed to maintain long-term effects. Sort, Set in Order and Shine must be completed before visualization can begin.

1. Human resources visual management: Identify and manage the work skills, status, position and performance of employees so as to understand the status of employees at a glance and implement assessment and education for employees.
2. Items visual management: including the management of various items such as fixtures, measuring instruments, equipment spare parts, consumables, materials, products in progress, and finished products. The purpose of visual management of items is to mark the original location of all items that may be moved, ensure that the items are returned, make the reorganization habitual, and know the number, type, and location of the items.
3. Operation visual management includes managing production operations and improvement activities such as operations, production progress and status, 5S and improvement proposals, and material distribution. Its meaning is to judge whether the operation is carried out correctly as required, whether the production is proceeding as planned, and to know how to respond if an abnormality occurs.

4. Equipment visual management: including the management of machinery and equipment in production workshops such as machine tools, pipelines, motors, distribution boxes, and electric control boxes. Its purpose is to implement daily maintenance work accurately and efficiently, such as cleaning, spot inspection, refuelling, tightening, and achieving "0" failure of the equipment.
5. Safety visual management: Manage the hidden dangers such as sharp corners of the workshop, electrolyte, electrical boxes, etc. Its purpose is to expose dangerous things and objects, stimulate people's vision, awaken people's safety awareness, and prevent accidents and disasters.

AHP

Analytic Hierarchy Process (AHP) is a systematic and hierarchical analysis method that combines qualitative and quantitative analysis. The characteristic of this method is that based on in-depth research on the influencing factors and internal relationships of complex decision-making problems. It uses less quantitative information to mathematicize the thinking process of decision-making, thereby providing multi-objective, multi-criteria or Complex decision-making problems with unstructured characteristics provide simple decision-making methods. It is a model and method for making decisions on complex systems that are difficult to fully quantify. (Saaty, 1987)

The principle of analytic hierarchy process,

The analytic hierarchy process decomposes the problem into different components according to the attributes of the problem and the overall goal to be achieved. It combines the factors at different levels according to the interrelationship between the factors and the affiliation relationship, forming a multi-level analysis structure model, so that the problem is ultimately reduced to the lowest level (plans for decision-making, measures, etc.) relative to the highest level (overall goal) to determine the relative importance of the weight.

The steps of the Analytic Hierarchy Process, when using Analytic Hierarchy Process to construct a system model, it can be roughly divided into the following steps:

1. Establish a hierarchical structure model
2. Construct matrix
3. Priority scale and consistency check

AHP helps to incorporate a group consensus. In general, this consists of a survey for comparison of each factor and a regular mean to come up with a final result. The hierarchy method that been used in AHP has many benefits for the company that uses it. (Vaidya and Kumar, 2006)

Positioning

Positioning is that uses reasonable analysis and research on the connections between various factors in the workplace, including people, objects, and sites, so that the workplace can be better integrated. It is the key mothed in that used in Seiton. Based on the unified planning, rectification, and treatment of all items in the workplace, the efficiency of workers and machines between various production steps is improved, and a neat, clean and refreshing environment is provided to all staff.

After the workplace has been sorted, all non-essentials are cleaned up. The remaining essentials are placed in suitable positions according to certain usage rules so that workers can easily find them. At the same time, the designation of places for tools, machines, materials in the workplace can avoid some unsafe behaviours and hidden dangers, making the entire work process more effective and safer, and improving the effectiveness of the workplace.

The basic content of the positioning

(1) Reasonable planning of the production plant area. Through the unified planning and design of all workshops in the entire factory, the production site and the placement of various items in the site are rationally arranged.

(2) Reasonable planning of workshops in production areas. Divide workshops according to different types of production and organize scientific planning and arrangement of the workshop layout.

(3) Reasonable planning of storage sites. By scientifically classifying the storage conditions of different items, arrange a fixed map of the storage site.

(4) Reasonable planning of office space. Set up scientifically according to the different needs of office employees and different documents.

3. Research Methodology

3.1 PDCA cycle

The purpose of this research is to help the company to apply 5S methodology into their small-scale production site. By daily involved in the production and department meeting, to get needed data and understanding of the company, combined with theory and practice case study from articles, then solve the research related existing and potential problems in the company, which would lay the foundation for the company.

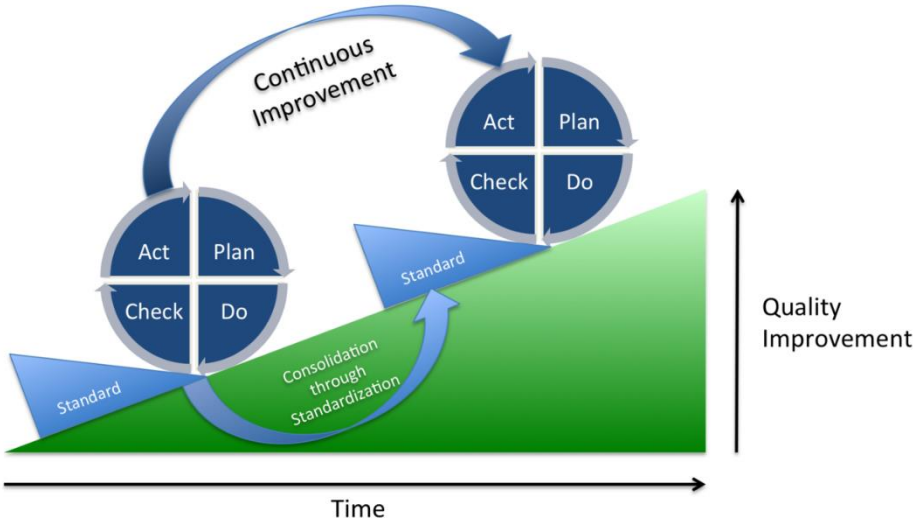

Figure 3. PDCA cycle

The definition to PDCA cycle

The PDCA cycle was made popular by W.Edwards Deming. It is a scientific procedure for total quality management that requires a comprehensive use of different types of management methods.

Formed by four letters, PDCA refers to Plan, Do, Check and Action, which are the fundamental procedures for continuous improvement. 'Plan' refers to set goal and objective of improvement and the carry out the program. 'Do' refer to take action, and 'Check' means to ensure each step is carried accordingly to plan, whether expected objectives are fulfilled in the process. 'Action' refers to a new cycle of implementation of different objective, and standardize what have been achieved, so the problem can be solved once for all.

The characteristics of the PDCA cycle

PDCA cycle is a method that allows people to think and to act in a systemic manner. The phase of 'Do' is the most important part of the PDCA cycle since it deals with existed problems and summarizes experience.

The focus is on the development of standards, such as technical standards and management systems. Otherwise, the PDCA cycle may not be utilized. The PDCA cycle contains three characters.

First of all, Planning, Do, Check and Action are interconnected to form an interconnected system to promote the program's development and ensure the program's execution. The complete implementation of Planning, Do and Check is the basic guarantee for the operation of the main system. As the basic method of quality management, the PDCA cycle is suitable for overall quality management and suitable for employees' self-improvement. Each department can design its own PDCA cycle according to the goal.

Second, the PDCA cycle can be used for continuous improvement. It is designed to solve the problem. When the difficulty is solved, it will move on to solve another new problem. During the continuous cycle, the production quality gradually improves.

Third, the progress of PDCA is made gradually. As shown in the figure, each PDCA cycle focuses on a specific goal. In this process, a certain number of problems were solved, and as the cycle progressed, the work efficiency level was further improved. Therefore, the various PDCA cycles are not at the same level. After each cycle, a summary should be made to summarize the experience and check results, and then new goals should be proposed.

Contents of the PDCA cycle methodology

Phase P

At this stage, first thing that needs to do is to choose a goal and analyze the current state. The theme of the cycle should be determined based on the analysis of the company itself.

Secondly, finding the cause of the problem and establishing a specific goal for next step. Scientific methods such as brainstorming can be used to find out the cause. Establishing goals requires clear content and specific standards.

Third, both employees and managers can propose different solutions to the problem. The key to solving the problem is to distinguish between primary and secondary causes. Therefore, the best solution can be selected based on the cause analysis.

Lastly, viable solutions require attention to detail. Whether the solution solves the problem depends on the specific procedures of the plan.

Stage D. In this stage, after a specific plan is designed based on predetermined standards, the corresponding overall arrangement can be carried out. Based on the known internal and external environmental information, people can make feasible plans and make appropriate decisions. Measures should be taken in accordance with the plan, and appropriate measurements can be taken to ensure that the program is under control. In addition, the original data and records related to the implementation should be collected and recorded as a document.

The check that needs to be done in Phase C is to check whether the plan has achieved the goal by careful evaluation. If the expected result dose not shown, it is needed to check each step to eliminate the cause of maloperation. Then, a new solution should be arranged to solve the problem.

Stage A. At this stage, the previous stage should have been carried out, and certain achievements have been made. What the organization needs to do is to arrange things and establish standards to maintain successful results and accumulate experience, which is the basis for further development. In addition, regarding the remaining problems, the company should make a comprehensive summary of the problems and try to solve new problems in another cycle. It is impossible to solve all problems in one PDCA cycle, and the remaining problems can be set as the target of the next PDCA cycle. Therefore, in the long run, the problem will be solved gradually, and the enterprise will continue to make progress.

In the first phase of the PDCA of this research, which is the Plan phase, case study and literature review are done by reading and on-site participation.

In the "Do" phase, is the implementation of 5s. In the Check phase, the result will be evaluated, followed by the 'Act' phase, which will standardize the achievement and propose further improvement suggestion.

The steps are based on the two frameworks for 5s, from the proposed implementing steps of the Japan Institute of Plant Maintenance with experience from successful cases in practice. Since there are many types of 5S methodologies, modifications are made based on the idea of PDCA cycle to merge them together into one applicable framework as shown below.

Table 1. Implementation framework

Step	Main function	What	Related philosophy	Stage of PDCA
Understand the case	Analysis the case from different perspectives	Organization, production process, machine and working environment state, Quality indicators.	Positivism,	Plan
Establish a 5S Steering Committee	The implementation of 5S activities requires the establishment of an implementation committee and a clear division of responsibilities, so that 5S can be implemented in an organized, planned and systematic manner, making it a daily management project.	Front line operator, engineer, production manager, administer staff.	Critical Realism, Pragmatism	Plan

Define a 5S Implementation Plan	Formulate a 5S daily activity implementation plan as a basis for the progress of 5S activity promotion and import it into daily management activities to strengthen the company's operational capabilities and competitiveness.	Based on the data and current state, analysis it and conclude a suitable implementation plan.	Constructivism, Interpretivism	Plan
Provide 5S Training & Education	Let every employee understand the content and meaning of 5S, and create a clean, orderly workplace that can implement visual management.	Daily meeting, slogan, board at the work place, education courses.	Constructivism, Interpretivism	Plan
Start 5s Pilots	Implement 5S activities in an example room	Example room for 5s	Positivism and Interpretivism Postmodernism	Do
Thorough implementation of 5S	Implement 5s	After making accordingly adjustment, apply them thoroughly.	Constructivism and Interpretivism	Do
Conduct 5S Audits	Hold regular seminars to brainstorm ideas to achieve a multiplier effect. Organize and implement site inspections irregularly and from time to time, and find defects and form records.	Use data to evaluate and keep the succession of 5s	Interpretivism Postmodernism	Check
Review & Improve	Finalize it and keep repeating some process, compare the data to make final conclusion.	Changing and upgrading to make them more appliable.	Interpretivism	Action

3.2 Research Methods and Techniques

The detailed research methods are presented in the table below. The focus of this research is more on how to apply techniques according to the theory, after defining the problems and figuring the mechanism behind them. The research has used many techniques, and the front-line operators apply some techniques. The table below shows some of the main techniques to show the idea. Those techniques will be divided more specifically in the implementation chapter.

Table 2. Research methods

Extract requirements from stakeholders and use 5S check sheet	Preliminary data, Literatures	Gather data from personal operation, and observation, giving out the score sheet	Analysis about the current state by using what been found from literatures.(Fish bone)	Interviewed more than on expert and several departments.
Build steps for implementation	Red tag methodology for Sort,	Example room as the reference for evaluating	Kanban methodology	Visual inspection
Identification management	AHP analysis	PDCA definition for the research	Warehouse management	The steps were verified with experts

Data source and the analysis

This part explains how to carry the Check part of the PDCA cycle by using the AHP methodology. Firstly, categories all the problems on-site into fishbone diagram, follow the procedure shown below:

(1) Find the problem to be solved.

(2) Write the question on the head of the fish bone.

(3) Convene colleagues to discuss possible causes of problems and find out as many problems as possible.

(4) Group the same questions and mark them on the fish bones.

(5) Ask everyone's opinions based on different issues and sum up the correct reasons.

(6) Come up with any question and study why such a problem arises.

(7) Ask why for the answer to the question.

(8) Research and sort out the problems, discuss them at the 5S meeting, and make 5S check sheets corresponding to the problems raised by the fishbone diagram for on-site use.

Check sheets for Sort, Set in order, Shine, Standardize, Sustain, are distributed to operators, engineers and managers, then based on the score, In addition to checking daily activity by sheet, it is also necessary to use visual inspection to evaluate the overall implementation status of each area. Aiming at the characteristics of 5S, the Analytic Hierarchy Process (AHP) is used to compare the achievements of different areas.

Both the company developed one, and the commonly used one is utilized in this research, the company developed one is used for AHP methodology.

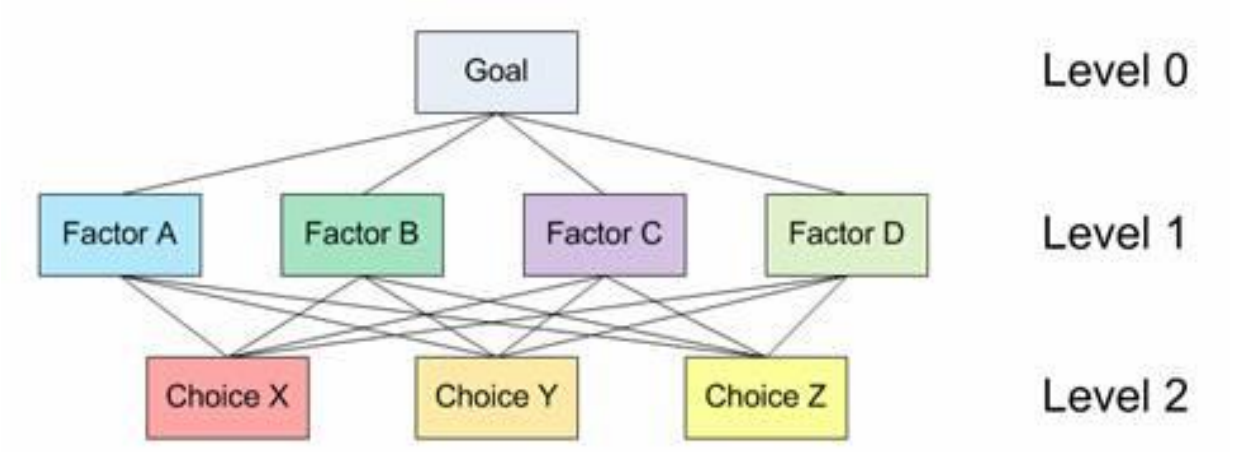

Figure 4. AHP methodology levels

1. Build the hierarchy structure.

The structure for analyzing implementation status is divided into 3 levels.

1.1 The 0 level is the overall goal of the analysis, to show different areas' implementing status in quantitative manner.

1.2 The level 1 is made up of key factors that are concerned in this case, they are the 5S.

1.3 The level 2 is the choices, in this research, they are specified as different operation areas.

Constructing Comparison Matrix

Construct a pairwise comparison matrix. After the goal hierarchy is established, the affiliation relationship between the upper and lower levels of indicators is determined. For the same level of indicators, compare the relative importance of the two elements to a number. The following table explains the scale of relative importance.

Suppose there are n schemes, C1, C2, …Cn, given a criterion, using the above relative importance scale method, comparing the elements Ci and Cj with each other, a number aij representing the relative importance can be obtained. In this way, the matrix is formed:

Equation 1. Form Matrix

$$A=\begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ & \cdots & & \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix}$$

The priority vector and the largest Eigen value can be obtained from the matrix.

The equation below shows the mathematic way of calculating λmax, which will be used in the Comparison Matrix in chapter that analyze and compare the outcome in workshops from the aspect of the 5S.

Equation 2. Calculate λ max

$$\lambda_{max}=\frac{1}{n}\sum_{i=1}^{n}\frac{(\hat{AW})_i}{\hat{w}_i}$$

W: Vetor of the matrix w: Eigenvector from the matrix

Followed by that, is the calculation of the consistency index CI of matrix, which is in order to test the reliability or consistency. As the equation shows below,

Equation 3. Calculate CI.

$$CI=\frac{\lambda_{MAX}-n}{n-1}$$

Correspond to what been mentioned in the literature review chapter, the use of CI is introduced as a one-time index of the judgment matrix in the analytic hierarchy process.

RI is introduced as an indicator for average consistency indicator that pre-determined by n.

When calculating the consistency ratio CR=0, A has complete consistency; when CR<0.1, A has satisfactory consistency, when CR≥0.1, it should be adjusted or discarded.

Equation 4. Calculate CR

$$CR = \frac{CI}{RI}$$

And table below shows the random consistency Index that has been calculated (RI):

Table 3. RI Index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Afterwards, the composite weight for the level 1 and the level two will be calculated in the matrixes, the first one would give composite weight to each S of the 5S, to show the importance of each S in the view of company's employees, then all the level 1 will be given a value by each factor which forms the level 2 (One specified S from 5S), to reduce replication, the detailed calculation process will be shown on the analysis chapter when comparing 5S performance of different rooms.

It is clear that the developed research design proposes only one iteration of development, one case which is the production site, and two time points (before and after 5S implementation).

4. Case and Problem Description of the Battery Cell Manufacturer

4.1 Company Description

Beyonder is a battery company that founded in 2016, specialized in research, production, and sale of energy efficient batteries for mainly industry purpose, from microgrids for offshore oil and gas rigs, busses with pantographs, microgrids and UPS for industrial buildings, offshore energy infrastructure and battery for trucks and heavy duty vehicles. The production site locals at Forus in Stavanger where they do research and development to ensure quality of the battery to meet market demand. In late 2021, the company will officially publicize its production, with the mass scale production site being built.

4.2 Structure of the Organization

In Beyonder, as a new energy company, the structure of the organization is clear and flat, and departments are functioning properly. The chain of command of Beyonder is drawn below.

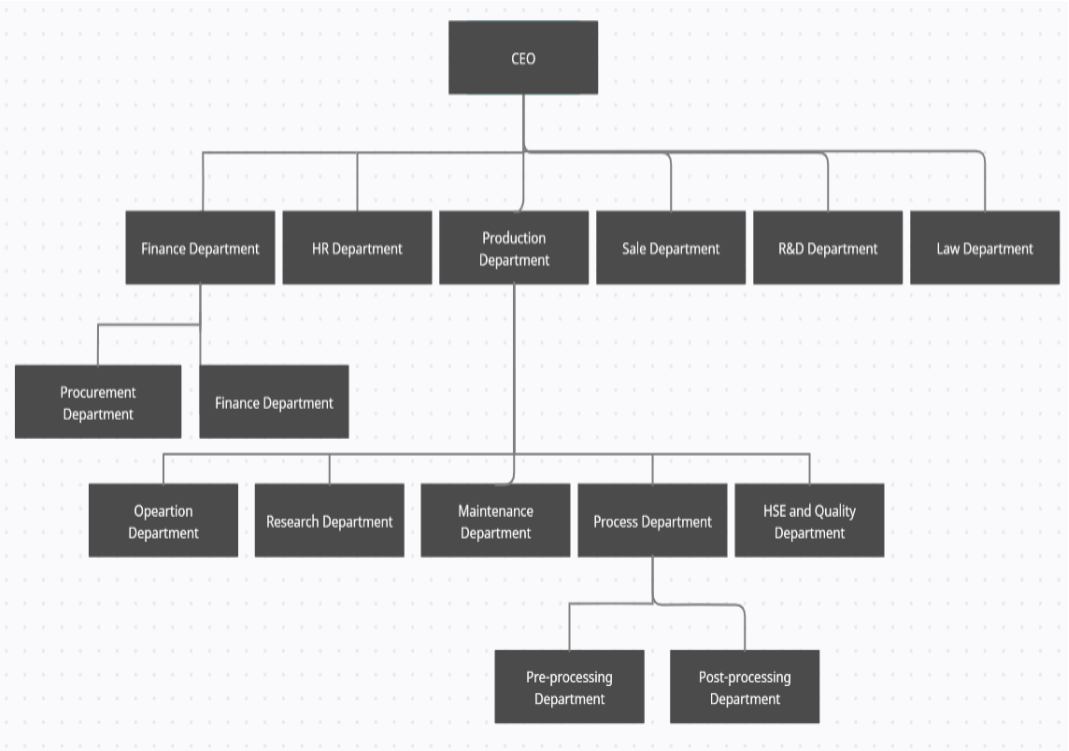

Figure 5. Organize structure

This research is mainly supported by the production department, with active participation of the Supply department, HSE department and R&D department.

4.3 Production Process

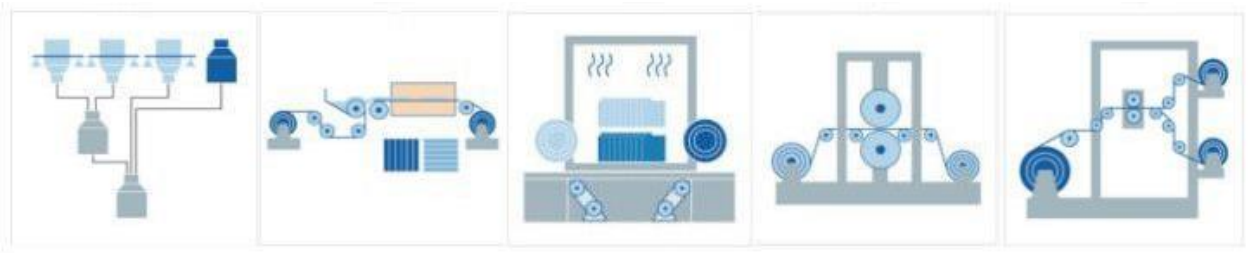

Figure 6. Processes in Production :Mixing, Coating, Drying, Roller Pressing and Slitting.

Mixing: Mix electrode active materials, binders, solvents, etc., and stir and disperse sufficiently to form a slurry.

Coating: Coat the prepared slurry evenly on the current collector (aluminum foil or copper foil, etc.) with a specified thickness.

Baking: high-temperature baking and drying treatment.

"Mixing" and "drying" are related. "Drying" is to better fix the mixed slurry on aluminum foil or copper foil. The next step is the production of single cells, after completing the above electrode drying process, rolling presses the coated positive and negative materials to make them more compact and adhere to the aluminum foil or copper foil.

Then followed by cutting: Slitting the rolled material into strips according to the process standard.

In order to prevent the dried electrodes from absorbing moisture again, the entire production process of single cells needs to be carried out in a dry room.

The positive and negative rolls are firstly punched to obtain pole pieces of a specific shape, and then the stacking process is performed. The positive or negative foils are selected to use a continuous separator, and the punched positive and negative pieces are placed in the middle of the separator.

The produced battery cell first needs to be welded to the tab. The tab welding method is mainly ultrasonic welding, followed by the shelling process. After the cell surface of the welded tab is covered with a protective film, it is installed into the battery shell. Then, the upper cover and outer shell of the battery are welded together by laser welding.

After the welding is completed, it is usually necessary to conduct a leak detection and reduce the humidity with the drying room.

The battery that has been screened for leak detection then goes to the very important injection process. Since the electrolyte of lithium ion batteries is very sensitive to moisture, the Vacuum injection process must be carried out inside the drying room. In order to improve the infiltration

effect of the electrolyte. After that, the degassing process is performed to eliminate bubbles occurs in cell.

The battery fully infiltrated by the electrolyte then enters the formation process, which is mainly activated by charging and discharging the battery with a small current.

The formed battery also needs to be aged. This is to put the fully charged battery at a certain temperature, which can eliminate those batteries with unqualified self-discharge and unqualified internal resistance, to improve the consistency of single cell.

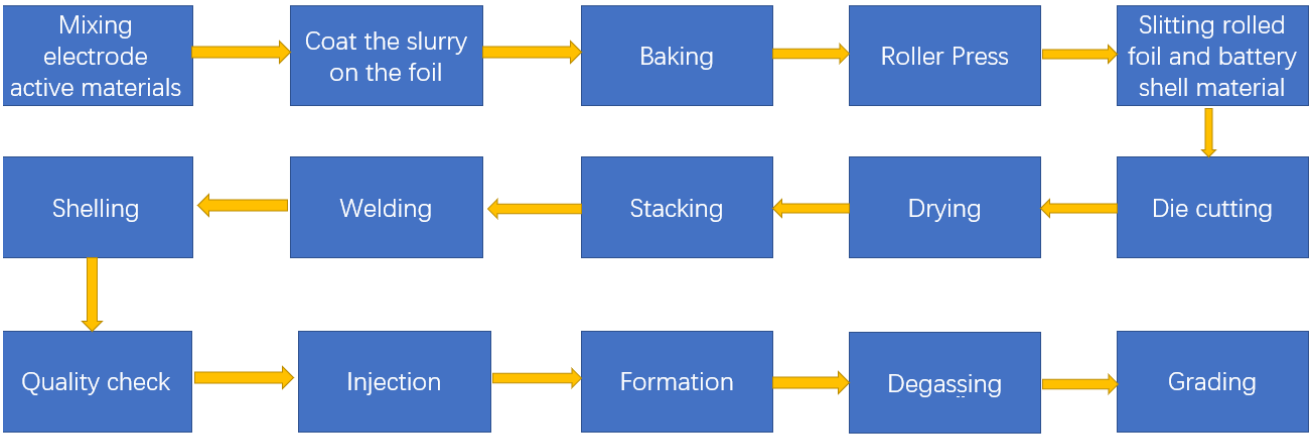

Figure 7. One Common Battery Production Process Flow

4.4 Current state and problems in production site management

The basis of 5S methodology is to find problems through comprehensive and in-depth analysis of the work site, propose improvement methods and then solve the problems. In the process of further development and growth, the enterprise keeps discovering many deficiencies in the workplace. After analyzing and inspecting the worksite before implementation, the following problems were found.

(1) The employees have insufficient ability to detect abnormalities and manage them. Some operators have not found any problems for several months, and abnormalities, such as equipment loosening, deformation, oil shortage, and pollution are obviously not included in the management.

(2) The production team did not strictly implement the cleaning, lubrication, and preservation operations in accordance with the benchmarks.

(3) The workshop's implementation of the requirements for on-site management has been discounted, resulting in the weakening of the company's and factory's standards to the production team, such as: workshop cleaning was not implemented as planned, items were not tracked, monthly activity reports were not timely, etc.

4.4.1 Current status of materials on-site and in warehouse

The placement of items on the work site affects the quality and efficiency of product production, which is one of the most important issues to be resolved.

Undefined Responsible area and machine

The responsibility for managing working area and machines are not allocated clearly, which reduce the working effectiveness and efficiency. For example, workers in mixing room are responsible for the tidiness of mixing machine and surrounding areas, while cleaning of the hallway is not allocated to anyone, so they have to clean the area although it is not their duty, as the consequence of the ambiguity of the responsibility zone on site.

1. Material classification problem

The necessities of the worksite and warehouse have not been reasonably positioned. According to the 5S management guidelines, it should be set according to the volume, weight, attributes, and usage times of different necessities. From the actual point of view of the production workshop, the item positioning is not achieved.

2. Material placement problem

Although the item placement area has been determined, it has not been classified according to the attributes of each item, which not only increases the search time during the use of necessities but also makes items mixed with each other and affects their quality. And the material is stacked on the ground in the warehouse, which is impropriated in consideration of safety, and it is not easy to distinguish or get.

3. Current state of tool management

The meaning of tool management: The tools used in operation may be fixed and dealt with. The way the tools are handled affects the safety of the production site and reduces production efficiency.

4.4.2. Tool placement problem

In the product production process, many tools are placed everywhere after they have been used, which greatly destroying the neat, clean, and refreshing environment of the work site. At the same time, because some tools do not have a fixed position, they are not easy to find when they are used, which causes inconvenience in work. In addition, there are still some tools that have not been properly kept, which ultimately results in a greatly shortened service life of these tools.

Although some tools were placed in the toolbox and in a location that met the standards in accordance with the site management rules, they were not returned to their original positions after use, nor were they properly handled. There are two specific reasons. The first is that the training of

employees is not in place and they cannot understand the 5S idea well. Some people have never heard of the 5S idea. The second is that the placement of the tools is unreasonable, operator may not get the required items accurately, thus wasting time and causing work inconvenience.

Operator Knowledge for work

The personnel play a decisive role in the production site, and at the same time, the personnel can guarantee the production efficiency of the enterprise on a certain basis. Therefore, the work mood of the personnel will have a certain impact on all aspects of the work site, and the work quality of the personnel is also a key factor. While most of the operator does not have an adequate level of knowledge of machine they are operating, how to maintain equipment and what to deal with if there is a small malfunction or failure.

4.4.3 Standardization.

The staff must work in accordance with the standard process flow at the production site. However, some workers ignore the importance of the process flow, do not follow the correct steps, and some do not follow the relevant regulations when restoring the tooling. There are two reasons for this phenomenon. One is that part of the process design is not reasonable and needs to be improved. The other is the lack of awareness of the employees themselves. And no matter what the reason is, if a certain procedure is not followed in a strict operation site, it will greatly increase the probability of danger.

4.4.4 Continuous optimization.

When communicating with on-site staff, it was found that many staff lacked the idea of 5S continuous optimization. The management of the production site of the enterprise should always be in a state of continuous improvement, and at the same time, there must be some thinking and progress in the improvement. The continuous optimization consciousness of the on-site personnel can be said to be the source of thought of 5S management. The reason for this phenomenon is the lack of training and education on 5S thinking for employees.

4.4.5 Work discipline.

During working hours, employees have shifting jobs and chatting. Some employees have low safety awareness and do not wear safety shoes, protection glass and earplugs.

4.4.6 Current operation environments

Production is completed in the on-site environment. The quality of the environment not only affects the cleanliness and order of the site, but also affects the working mood of employees and reduces their work efficiency.

1. The problem of dirty environment.

There is generally oil pollution on the machine and the ground, and there cannot be too many items in the actual production site. However, some employees' personal belongings and mixed tooling accessories are piled up on site, which not only increases management costs, but also takes up the originally very limited operating space. This phenomenon eventually leads to a continuous decline in production efficiency, which indirectly increases the labor time and work intensity of employees. During the processing, different solvents and liquids could drop on floor, the alignment of machine might be influenced by the dust, and contamination areas have potential damage for equipment operator.

2. Facilities issues.

At the production site, the placement and layout of some machinery and facilities are not reasonable. The work area that operated by one should be operated separately by two people due to the placement sequence.

4.4.7 Current status of document management

The company has multiple departments with different functions, and each department is responsible for different scopes of work. The relevant documents naturally have different functions. Different departments need to store different paper documents, and at the same time, they have to deal with different types of documents as required. Before the implementation of 5S, there was no very systematic arrangement plan. Each department has its own way of storing documents, which is prone to the following problems:

1. It takes a long time to get the documents. The author encountered this problem at that time. There are documents and invoices with different contents on a cashier file. It takes a long time to find a blank bill of exchange.

2. Improper storage. Regardless of whether important or unimportant documents are put together, there is a lack of document management awareness.

3. The file tracking program has not been set up, and the probability of questionnaire loss is too high. Prior to the implementation of 5S, the company’s purchasing department did not follow up important purchase orders, and often lost purchase orders, which extended the working time of the operation department and delayed work.

4.4.8 Lack of sufficient attention

The company's goal of on-site management is only to ensure the quality is in place. For the safety of the production environment, it lacks sufficient management awareness, so that the company's minor accidents and employee work-related accidents occur from time to time.

On-site management is not only the competitiveness of enterprises, but also the core competitiveness of manufacturing enterprises.

When formulating a clear corporate strategy, a very clear management strategy should be put forward. Some production sites seem to be safe and reasonable, but there are some risks hidden. When encountering emergencies, various hidden problems might follow one after another.

4.4.9 Lack of effective mechanism

There is a certain connection between the state of the enterprise site and the internal management mechanism of the enterprise. The company's on-site operation mechanism is not perfect, and it will be impossible to investigate and deal with emergencies. The content of the existing rules is not specific enough, and the operability of specific implementation is poor. The lack of a management mechanism eventually leads to problems in actual work. When the enterprise reaches a certain scale, the operation mode will undergo essential changes. Of course, traditional working methods cannot meet the corporate goals. At this time, the advantages of the management mechanism can be seen, and an effective management mechanism can make the work of the site go smoothly. Therefore, enterprises must formulate effective rules and regulations based on the characteristics of the products.

4.4.10 Reasoning problems at the production site

After investigating, and recording the on-site working problems, it is found that there are indeed some problems that cannot be ignored at the job site. The researcher believes that to carry out 5S management, it is necessary to eliminate the main reason for the problem.

5. Analysis and Results

Implementing 5S Methodology

Based on the problems mentioned in the previous case analysis section and following the proposed PDCA methodology, the implementation of 5S management starts in the case company.

5.1 Plan phase

Implementation quality is in the hands of promoting the 5S team so that employees can complete tasks smoothly and efficiently. Therefore, the establishment of a promotion organization is very important.

According to the characteristics of the company's organizational structure, it is very important to avoid major changes in the organizational framework and to ensure the sense of participation of all employees, which adds corresponding responsibilities to managers at all levels. The 5S Implementation Committee includes one implementation director (as the production director), responsible for the overall promotion and assessment and review of each stage, one project leader (as the researcher), responsible for planning and appraisal work, and one executive team (production Department, Process Department, R&D Department, Supply Department and HSE Department), the team leader is the manager of each department, responsible for leading the members of their own departments to carry out their work, solve related problems, summarize the relevant experience, and gradually complete the set goals. In addition, each department has an employee who records and communicates the morning meeting, takes responsibility for conveying the meeting minutes, coordinates various problems encountered on-site in implementing 5S, and reports the implementation of 5S in each department.

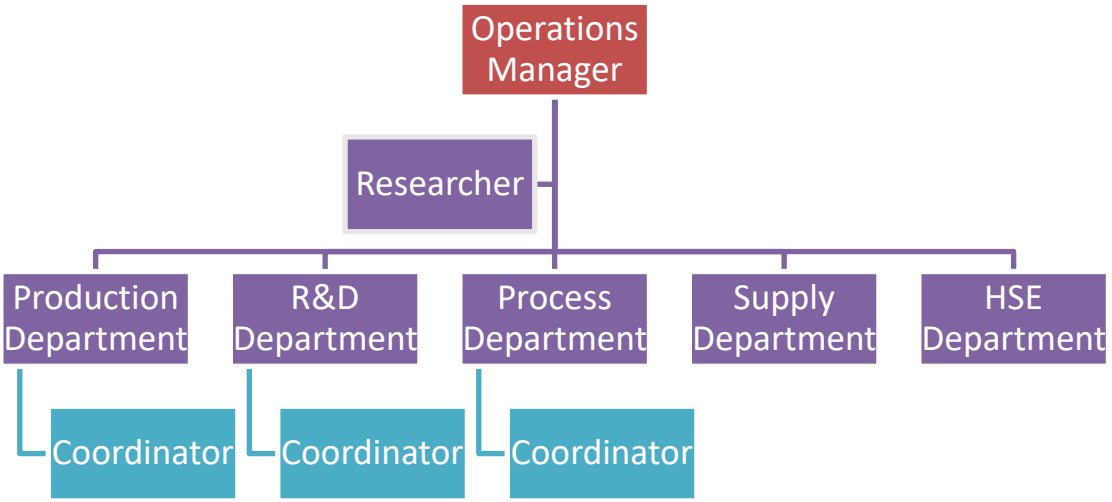

Figure 8. 5S Team

According to the 5S management methodology, the company has formulated the following implementation plan. Some of the more specific plans for each month, week and process are shown in the appendix, and the following plan is formed by PDCA phases, in which the main tasks of the above four stages are interrelated.

It should be done step by step during the implementation process, especially in the implementation phase of the first PDCA cycle. Then, in the future PDCA cycle, the company can focus on each stage according to its proposed improvement plan.

Table 4. PDCA phases with Plan

PHASE	NO.	Project	12/2020	01/2021	02/2021	03/2021	04/2021	05/2021
Plan	1	Form 5S Team		★				
	2	Define Plan	★					★
	3	Make related Document	★	★	★	★	★	★
	4	Promote and Educate		★				
Do	5	5S Pilot			★			
	6	Sort, Set in order, Shine				★	★	★
	7	Standerdize, Sustain					★	★
Check	8	Check					★	★
	9	Evaluate						★
Action	10	Anylysis						★
	11	Keep Improving						★

5.2 Education and Publicity

In the education stage, the company has carried out various forms of publicity activities, including slogans at the production site, holding educational meetings, issuing 5S manuals and distributing 5S score sheets, etc. One month of education and publicity activities created a strong 5S commitment.

And in the education and training stage, despite the different requirements for personnel at all levels for management, detailed education and training enable personnel at all levels, especially operators, to understand their responsibilities and how to perform their responsibilities.

5.3 Sort

5.3.1 Define responsible area

Since the operators will do the work, the responsible area is distributed accordingly to their workplace by the 5S team. The responsible area for front processes that involve more raw material and waste and tools, items, and equipment are divided smaller than the ending process, which is easier to manage and implement the 5S plan. As an example, the responsible areas for the second-floor middle-process are shown in the figure below.

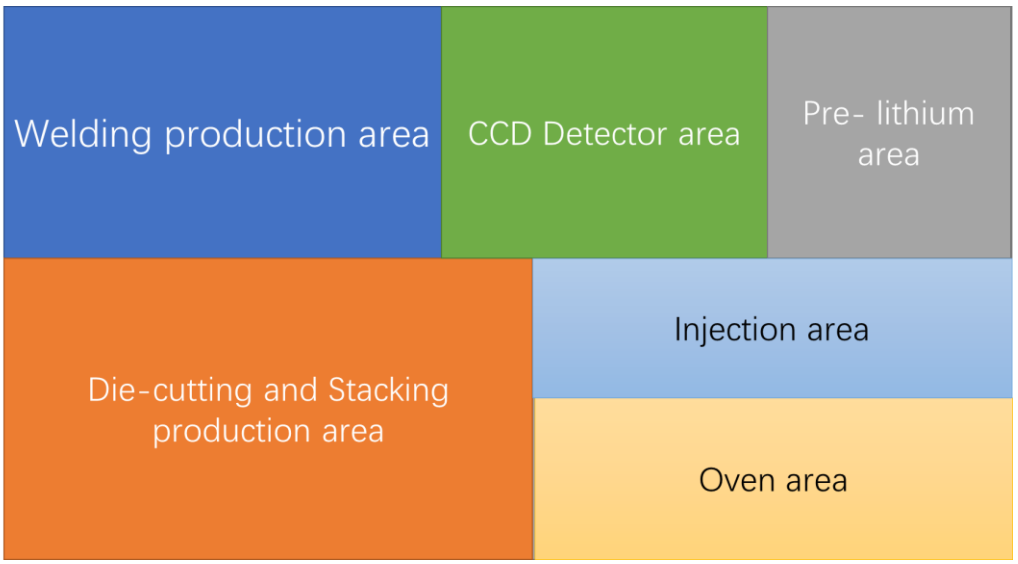

Figure 9. Responsible areas of the second-floor middle process

5.3.2 Red tagging

Red tagging is carried by the 5S team, and before executing, all items should be identified easily for tagging. It involves examining everything in the workplace. Whether there is wastepaper, scraps, waste materials on the floor, whether there is a safety hazard in the electrical thread, and whether

there is unnecessary and redundant data piled up in the desk and office area. More specific, the hanging tags, ceilings, lights, etc., in the corners are all within the inspection requirements. The idea is to remove all unnecessary objectives from the work area and surrounding areas.

There are the steps of carrying Red tagging:

1.Put red tags on items that are not needed in the workplace, and at the same time determine a period, require these marked items to be cleaned up during this period of time, so that the workspace is tidy and clean. The basic style of the red tag is as the figure shows below.

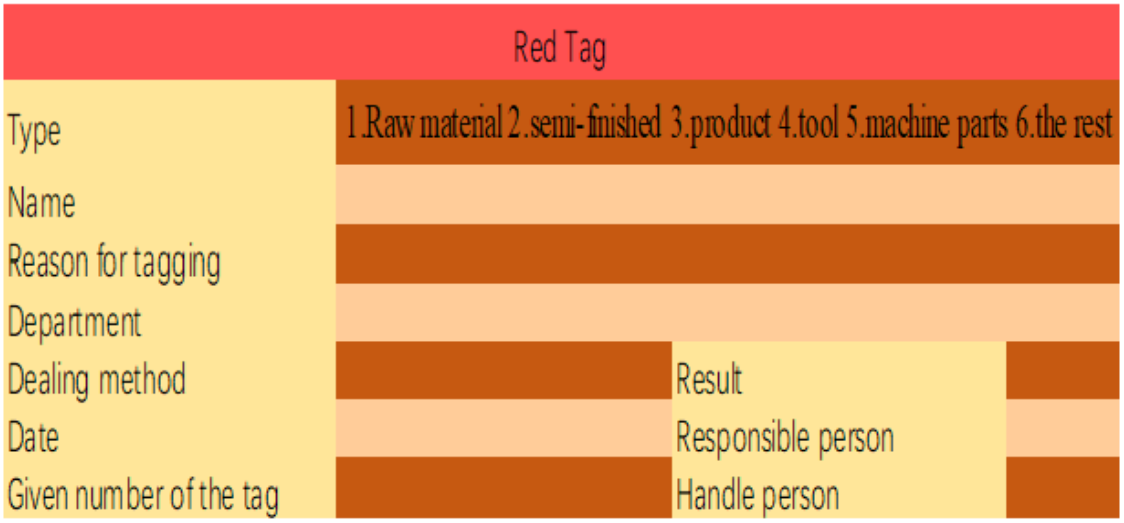

Figure 10. Red Tag

2.Issues that need to focus on in applying

(1) Formulation of red card standards. Because only unneeded items are marked, a distinction standard must be determined before distinguishing between needed and unnecessary items. For example, in order to complete the tasks within this week, the items needed are necessities and do not need to be given a red label. On the contrary, the items that are not needed must be labelled with a red label.

(2) The application of red card operations. The 5S team selects 2-3 operators whom go to different workplaces to carry out the "red labelling operation", and red labels the unnecessary items. They will red-tagging things when they feel uncertain about the necessity or suspect the frequency of usage of one item. At the beginning of the action, we must rationally analyze whether the item is needed and decisively put a red tag on non-essential items.

(3) Improving countermeasures for red card operations. Items that have been labeled must be sorted and sorted in a certain way. Items that are not used for a long time and items of substandard quality are required to be handled and thrown away by the responsible staff in a timely manner. As for some temporarily unused items, the storage location must be changed.

3. Precautions for the implementation of red card operations

(1) Before the red card operations, all staff need to be mobilized in advance, and the significance of educating them to carry out this action is to find the problems in the production process and make further improvements. All staff must actively cooperate the implementation of this action;

(2) There must be a reason for non-essential items that need to be marked.

(3) Marking non-essential items do not need to be carried frequently, just once every 30 days, and at least once every seven days.

Table 5. Material Classify Method

Needs	Redundant
Required materials	Personal belongings and damaged items
precious resources	Outdated decorations
Finished products, samples, etc.	Damaged electrical wires and other safety hazards
Booth, dust cover	Redundant reference books
Appliances, sanitary products	Tools that are not used in work
Sheet for recording	Items not related to work
Personal necessities	expired documents

After defining what is needed and what is not, items that stay will move to the next stage of 5S implementation, the rest items will be tagged and depending on the frequency of usage, if the tag stayed longer than a week while less than a month, it will be redistributed to the warehouse. And if it stays longer than one month and has no value in the foreseeable future, it will be either thrown, leased or sold.

Dealing method description

Accordingly, the sheet below shows the methods used to deal with the items after red tagging them. Most of the items are put into the warehouse, and in the following section, is to sort in company's warehouse, as the finalize step of the first "S".

Table 6. Material Dealing Method

Dealing method description	
Throw	things that no longer valuable to the company
Sell	No value to the company, but still value to other companies
Return	If the item is needed after checking, return to where it belongs
Leasing	Leasing for other enterprises

Redistribution	Put into warehouse

5.4 Carry out of Seiton (Set in Order)

5.4.1 Specific implementation steps

1. Carry out the previous step of sorting. First of all, sort out the items in each department to make more spare room in the workplace. It is also necessary to make the best use of the available parts and reduce unnecessary consumption and waste.

2. Arrange the process and determine the placement place. After sorting, the useless items have been cleaned up, and the rest are all needed items. First, place the items in the corresponding position according to the number of times of use (the ones that are used more frequently should be placed in a place where operator can easily reach them; the ones that are used more often are placed in a fixed location that is relatively close; those that are used less frequently are placed in the storage area).

3. The placement method and implement

Use the first-in-first-out method to improve the shelf's utilization rate and make use of its space. Put things of the same type in one place. The internal structure of the cabinet should be properly organized.

Regarding paper document, use boxes as a container to sort the documents and place them, and mark on the boxes. Then, put them in the cabinets in order by the type and year of the materials and make the sequence numbers.

5.4.2 Techniques for implementing Seiton

1. Establish an example room and try to implement it. The level of Seiton needs to be continuously improved.

The implementation should start from the high priority level. It is recommended to set a model of rectification and make thorough improvements. This will definitely yield something, and the experience gained from it can be widely understood and implemented in other rooms, and setting an example can achieve certain results without spending too much effort.

2. Basic Principles of Visual Management

Visual management uses various visual perception information with intuitive images and appropriate colors to organize on-site production activities to improve production efficiency and implement quality process control. Through the implementation of visual management, employees can immediately know the progress of various tasks through their eyes and react quickly.

The scope of visual management

It is including personnel, materials, equipment, etc., mainly through the use of corresponding signs. In terms of personnel identification, the larger the company, the greater the need for personnel identification to facilitate work. There are several types of jobs, job qualifications and skilled employee identification at the scene, which are generally distinguished by the color of the coat and hat, epaulettes, badges, and eye-catching signs.

In terms of material identification, one of the most error-prone items in the field is material identification, including identification of product name, number, quantity, origin, and status, identification of good and defective products, and identification of storage conditions.

There is visual management in terms of equipment identification such as equipment name, management number, accuracy calibration, operators, maintenance personnel, operating status, equipment location, safety escape, life-saving devices, and operation process indications. In addition, it also includes visual management of job identification, environmental identification, non-conforming product identification, safety identification, etc., as well as visual management of equipment status identification.

Visual management is a simple and very efficient management method. It can simplify many things on the production site, so that all relevant personnel on the site can know if there are any abnormalities at a glance. There is no need to waste the time of searching, the work efficiency will naturally increase, and the management work will become easier and more relaxed. The content and operation flow chart of visual management describes the operation sequence and concise instructions of key processes. The area line is the area where the equipment is placed or the channel and drawn with lines. Signal lights are used to help front-line managers understand whether workers or machines are operating normally, including sounding signal lights, abnormal signal lights, progress lights and operation indicators. Visible Board includes production management board, error statistics board, etc.

KanBan (Visible Board) Management

Refers to the disclosure of the desired project (information) through the visible board in 5S management. The main functions of Visible Board Management are as follows:

1. To convey the process of producing items in the workplace and to unify the understanding. There are many employees in the workplace, and it often happens that messages are not delivered on time due to the differences in the tasks they handle. Visible Board management allows all staff to find the work tasks and various messages of all on-site in Kanban, so that information can be communicated in time and effectively. At the same time, the staff can propose improvement methods for the deficiencies in the whole process of the production of items and publish them on the board that can actively communicate with everyone about the deficiencies. Apply the improved method to the production process, unify the staff's contributions, and draw them on board to work toward the same goal.

2. Avoid flaws in workplace management. The use of Kanban by management staff can provide reference opinions for management decision-making and enable them to have a more direct understanding of production status and product quality. The first KanBan is placed at the mixing room, which works as an example room for the 5S implementation.

Figure 11. On-site KanBan

3.After using Kanban, the performance of everyone in the workplace can be seen. Through an intuitive understanding, employees' work performance can be evaluated more objectively, and employees can encourage each other to supervise and improve work efficiency. Also, it ensures the production order in the workplace and maintains the brand effect of the company. The site kanban reminds the operating staff to perform production behaviors according to the production situation. It enables the worksite to perform more efficient production behaviors by positioning products and raw materials. At the same time, it can improve the satisfaction of visiting customers and maintain the company's brand effect.

Color management

Color management is to put a colored coat on the management activities and management objects in the enterprise, so that any management method uses the four colors of red, yellow, blue and green

to control, so that employees can naturally and consciously combine with traffic signs. , In order to promote consensus, sympathy, and mutual action of all employees, so as to achieve management goals. Color management makes use of people's natural sensitivity to color to achieve the goals of visible management, classified and hierarchical management, and toning the atmosphere of the work site. For example, the production progress status is distinguished by color, green means the progress is normal, blue means the progress is behind, yellow means production waiting, and red means mechanical failure. As the figure shows below, is the machine state color indicator for one of the mixing machines, which has been put in warehouse during the time of machine installation. After sorting the warehouse and pose the visual management related problems on site, the statue beam is installed on top of that mixer.

Figure 12. Statue Beam

In addition, the application scope of color management can also include the management of important parts, oil management, pipeline management, personnel management, document management, and raw materials management.

3. Another important factor of sorting is the convincing level of taking out items. Sometimes, it takes a lot of time to take items out because it is placed high or deep in the shelf. If it is an item placed on the ground, it is troublesome to bend over and take it. Therefore, It is vital to place frequently used items in the area consciously.

4. Drawing of line

It is important to return objects to their original places, so the place where the objects are placed must be clearly defined. For example, the anode and cathode material waste bin were randomly placed on site, while after applying this method, the line on the floor fix them in a suitable and fixed position.

In the process, 5S team concluded that marking is very important as it shows the purpose of one area and keeps non-operator away from potential risk and helps the fixing place of equipment. Lines are drawn beside aisles, equipment, tanks and other items to indicate clearly.

Figure 13. Fix position for trash bin

The line can also separate the aisle from the operating area, and it must be kept clean to make it clearly visible.

There are three types of line drawn on-site for equipment, tools, raw and waste material separately.

5. Reorganization of documents, materials, and tools

Workers often overlook the rectification of documents, materials and tools. Of course, it must be sorted first, especially the documents and materials. They are different from tools or parts, and the content is not clear at a glance. They are also hindering the reorganization process.

Fixing position Implementation

After finishing the first step of 5S implementation, the state between the remaining items and operator are analyzed according to the idea from the literature chapter that items should be put in the most suitable place where both convenient to access and easy to find. Three types of states are summarized by observing the production process of the first floor, mixing and coating processes in particular, and divided into three types.

A. Operator and items can form an entity that works on the desired outcome in a short period of time and performs effectively. For example, during the mixing process, the operator needs to stop the mixing machine, pour a small quantity of slurry sample out to test viscosity, solid content, fineness, etc. For example, if the testing instruments are placed scientifically, the operator can quickly access those instruments, thus shortening the time of mixing and overall process time.

B state: The operator is searching for a specific item or can not carry a task efficiently. For instance, when the toolbox is placed randomly, or the operator does not remember the place, it takes extra time to find, which could be avoided.

C state: The state that the operator needs to move longer than the case if the item placed as close as possible in the first place. For instance, the burin for anode foil was placed on the desk of the pre-lithium area. Each time an operator wants to use it to cut anode foil in the die-cutting area, they need to walk 10 meters to reach it and another 10 meters after usage.

This Seiton part aims to optimize C state, control and eliminate B state, trying to move them to state A and maintain what has been achieved.

Improvements are made in the following aspects:

Optimistic positioning

For items that can contribute to the bottle neck of the production, those items are placed on shelf that close enough for operator to reach, and the higher the frequency of usage of one item, the closer the position of it to operator. For instance, due to the fact that in the process of anode slurry mixing, electronic scale is used more than 3 times in average, while the filter for reducing granularity is used once per batch, therefore by comparisons the importance of all remaining items in workplace, things are placed at the most suitable area that reduce the working time as much as possible.

In the mean time, items that have nothing to do with the bottle neck, like cleaning tools which is used during the end of each batch, are placed one the other side of the area, so when production is done, operator could pass by the machine and use visual inspection to check if everything is in a good condition.

Fixing position for tools

In production, many tools are shared among different areas. If one operator does not return the tool on time or place it in position, it causes inconvenience for others. Therefore, the shelf is properly organized to ensure each tool has a fixed position with a label down below. The photos below show one out of many shelves' before and after applying for a fixing position.

Figure 14. Fix position for tools in Mixing room

Also, this measure makes the layout of tools spread evenly on the shelf, so they do not influence each other, and the operator can always realize what item is missing or in shortage by glancing at the tool cabinet and shelves.

Warehouse management.

Define the areas in warehouse

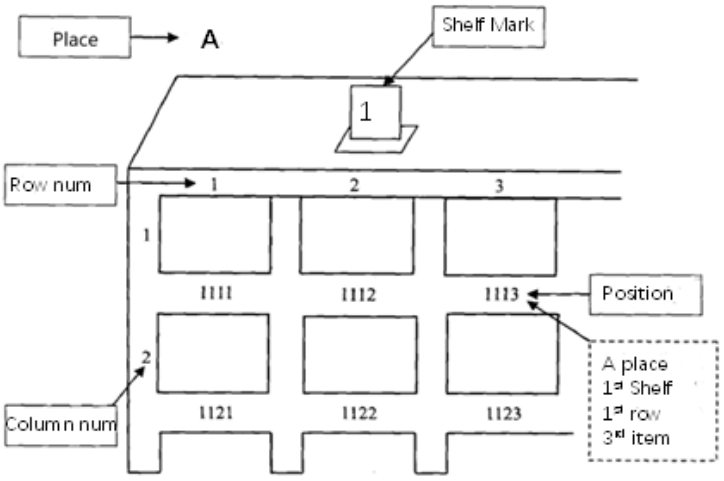

Figure 15. Define areas in warehouse

At the beginning of this research, goods were stacked on the floor and poorly managed. The supply department always had trouble in the warehouse. After sorting, in this Seiton stage, storage shelves

are made available. Hence the position for each good is easily defined according to its purpose. This method is based on some discussion and research about the scale of the production site.

Figure 16. Manage Warehouse in a Scientific way

To make it easier for engineer, supply manager and operator to find or describe the position of material or machine part in the warehouse. Rows of shelves in the warehouse are named and organized, and the related materials are put closely. After proper organizing, boxes are no longer stacking; both safety and efficiency are increased in the warehouse section. Also, each item will be given a 4 digital serial number, combined with the warehouse number, shelf number, layer number and position number, so the place of one specific item can be identified quickly.

5.5 Shine

5.5.1 General cleaning of the Shine stage

In this S, the 5S team made many sheet and the layout of the specific implementation of general cleaning of the Shine stage

The quality of the product is closely related to the cleanliness of the site. It is generally believed that "Shine" means simply sweeping the floor with a broom and wiping the equipment with a rag. In fact, the content of "Shine" is much more than that. The corners, column feet, ceilings and all corners of the production site must be thoroughly cleaned. In addition to removing stains and ensuring the health and safety of employees, it can also detect equipment abnormalities in time to achieve the purpose of preventive maintenance for all employees, keep the equipment in the best operating condition, and produce excellent products.

1. Implementation points

Operators maintain their own equipment, and frequently wipe their own tools without special cleaning workers, the cleaning of the equipment focuses on the maintenance of the equipment. The equipment cleaning is combined with the key points checking of the equipment, so that machine failures, malfunctions and instant downtime are minimized.

Cleaning is also for improvement. When pollution or anomalies are found, the root cause should be traced, and the recurrence of pollution and danger should be prevented.

2. Determine the objects to be cleaned. The objects to be cleaned are divided into three categories: storage places, mechanical equipment and sites. Where items are stacked include warehouses, shelves, work-in-process turnover areas, tool cabinets, etc.; mechanical equipment includes production equipment, handling machinery, tooling and molds, etc.; venues include passages, work areas, meeting rooms, toilets, etc. For each cleaning object, the corresponding cleaning method and the person responsible for cleaning must be determined.

3. Determine the responsibility for cleaning, which include preparation of layout plan for cleaning responsibilities, 5S team decided to use the floor plan of the workshop to divide the sanitary responsibility area, determine the responsible person, and announce it on the bulletin board. The responsible areas are all most the same as the areas that's been defined in the step of Seiton, Then develop a cleaning schedule for cleaning items, a schedule should be made to ensure the implementation of cleaning, especially for places that are used in common, a rotating duty system should be adopted, and corresponding inspection standards should be established.

4. Determine the specific time and content of cleaning:

Daily cleaning: clean the floor, passage, desk, window sill, toolbox, toilet, etc., five minutes before going to work every day.

Weekly cleaning: spend 30 minutes cleaning the stationery cabinets, lampshades, desks, etc. on the last working day of each week. Operators are required to clean carefully and clean corners, places that are not visible, and higher positions should be carefully cleaned. Also, the cleaning tools are arranged in a fixed place, and their placement should be easy to pick and place away from potential pollution area.

At this point, education for all participants got trained properly for Shine and did the initial cleaning within a week according to the previous plan.

Figure 17. Employees are shining the cylindering machine.

5. Issues that should be paid attention to during the cleaning phase

1.Only clean within the specified time, while ignoring it in daily operation

2.When the object to be cleaned is relatively high or far away, and it is difficult to reach by hand, then it is not cleaned.

3.The cleaning tools are ineffective, and a lot of dirt cannot be effectively cleaned.

5.5.2 The specific implementation of equipment checking of the Shine stage

Production equipment is high-speed, and highly automated. Once a failure occurs, it will shut down completely, affecting the entire production plan and causing significant economic losses to the enterprise. Equipment inspection can help operator accurately predict the service life of equipment, laying a foundation for the safe operation of equipment, reducing equipment accidents, and maximizing benefits. Therefore, equipment inspection is very important in production.

The Key points checking method is that inspects the specified parts of the equipment according to a certain standard and a certain period, so as to find the hidden troubles of the equipment earlier, repair and adjust it in time, and make the equipment maintain its specified functions. The equipment inspection system is not only an inspection method, but also a system and management method. Its essence is based on preventive maintenance and key points checking as the core. The enterprise implements the equipment maintenance mode with the key points checking as the core, so that the equipment management of the enterprise can be standardized, institutionalized, and standardized, and meet the requirements of modern production methods for process equipment, truly effectively prevent accidents and improve equipment management Level, ensure the reliable and efficient operation of production equipment, and improve the overall economic benefits of the enterprise.

Equipment key points checking standards are based on the functional and structural characteristics of each part of the equipment, and stipulate the basic items of inspection operations, focusing on inspection locations, items, content, inspection division, equipment inspection status, inspection methods, and judgment standards, etc.

Key points checking standards are the basis for preventive inspections of equipment, the standard basis for inspectors to carry out key point inspections, and the basis for the preparation of spot inspection plans and the preparation of inspection schedules, cards, and how to conduct inspections.

Specific rules for key point checking as a part of Shine.

There are eight rules for equipment inspection: fixed point, fixed method, fixed standard, fixed cycle, fixed state, fixed category, fixed procedure, and fixed personnel.

1 Determining principles of inspection locations (points) and items

Refers to the objects that are listed as preventive and predictive maintenance inspections, generally equipment parts that may fail or deteriorate, such as rotation and transmission parts, and parts in contact with raw materials, corrosion parts, load-bearing parts, electrical insulation parts and so on. Component inspection items, such as bearings of the rotating part, gears or racks of the transmission part, disassembly inspection, etc. are also included.

2 Content creation

The content of the inspection item ---- refers to the diagnosis element of the deterioration inspection item of the part.

Some elements of machinery and equipment inspection:

Pressure, temperature and humidity, flow, leakage, lubrication status, abnormal noise, vibration, wear, cracks (breakage), loose, aging, etc.

3 Checking steps

Compile the content of the component inspection by the five senses.

Compile the content of managed items, including cleaning, tightening, adjustment, disassembly inspection, replacement parts, cycle repair parts, etc. Precise inspection content, such as vibration measurement, sonic flaw detection, Infrared flaw detection, etc.

4. Check status

According to whether it is necessary to stop the inspection, the inspection standard is divided into three equipment states: shutdown, operation, and unrestricted.

Shutdown point inspection: the point inspection when the equipment is stopped. Shutdown inspection includes static inspection items, such as wear, slack, cracks (corrosion), etc.; it also includes disassembly inspection, cleaning, and tightening during equipment maintenance.

Operation inspection: the equipment is in operation status inspection, such as pressure, flow, temperature, leakage, abnormal sound, vibration, oil supply status, etc.;

Unrestricted: Refers to inspection items that can be inspected both in the stopped state and in the stationary state.

5. Inspection standard classification

1. The inspection standard is the basis for measuring or judging whether the inspection site is normal. It is divided into qualitative standards and quantitative standards;

2. Different types of equipment is divided into general inspection standards and special inspection standards;

3. The inspection interval is divided into daily inspection standards and period inspection standards.

Below is one example of the cleaning sheet that been developed by the researcher with the front process engineer.

Equipment daily cleaning and maintenance record sheet																	
Equipment Name:Oven				Machine No.:									month:		Years:		
	The date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Daily Cleaning Content	Equipment surface cleaning																
	Clean the inside of the oven																
	Operation panel cleaning																
	Vacuum pump cleaning																
	Material rack cleaning																
	The recorder																
	The supervisor																
	The date	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Daily Cleaning Content	Equipment surface cleaning																
	Clean the inside of the oven																
	Operation panel cleaning																
	Vacuum pump cleaning																
	Material rack cleaning																
	The recorder																
	The supervisor																
Other cleaning contents		Cleaning date	supervisor	Cleaning date	supervisor	Cleaning date	supervisor	Cleaning date	supervisor	Cleaning date	supervisor	Cleaning date	supervisor	Cleaning date	supervisor	Cleaning date	supervisor
	Cable clean																
Remarks: daily cleaning - cleaning once per shift, other cleaning items can be cleaned according to SOP requirements																	

Figure 18. Developed Sheet for Equipment Cleaning and Maintenance

5.6 Standardize

The specific implementation of Standardize stage

Different from the previous one, standardize is to maintain the state of results. It has the closest relationship with the front-in-the-middle cleaning. It is required that the equipment operator carry out the necessary maintenance activities (cleaning, tightening, lubricating) for the equipment they operate.

5S requires to meet the previous 3S, and maintaining the achieved state for a long time is "standardize"; to find out the root cause of equipment leakage and oil leakage, and eradicate it from the source, this is also "Standardize". Standardize is scientifically sophisticated with tracing the source, starting from the details, creating a clean and tidy environment.

The specific implementation steps are as follows:

1. Try to develop the habit of standardize, develop various standards and systems through education and training, and help employees develop neat habits.
2. Divide the responsibility area for standardization, set the responsible person, mark the name of the responsible person and the responsible content in a more obvious way, and post or hang it in a conspicuous place in the workshop to strengthen management.
3. Cooperate with the daily cleaning to make the equipment standardize inspection table and develop the corresponding standardize inspection chart to different types of equipment.
4. Every two weeks, it is agreed among all related employees from different departments and sections to go through the whole plant and check what others been missing for the previous 3S on their responsible area or what can be improved.

To keep achievement in standardize

Only if the 3S is completed, and the existing results can be maintained and improved, the effect of Standardization can naturally be achieved. In the process of advancing 3S, the safety, quality, efficiency, and cleanliness of the production site will be improved. However, it will be difficult to maintain such results for a long time. If people are too satisfied with the status quo in the middle of the Do phase, the site condition may return to the original state before implementing 3S. Therefore, the following points should be made in actual operation.

1. Pay attention to visualization and display

Visualization is the key to standardization. The visualization used in "Seiton" is also important for Standardization. It is also important to use visualization to notice abnormal to maintain Standardization. As mentioned in the "Shine" sector, the advanced the visualization and actively

display it to the workshop, the more standardization level will be achieved. Actively showing the internal situation of the factory to customers can inspire employees to maintain Standardization.

2. Keep staff's work clothes tidy

Operators should first keep themselves tidy. It can be thoroughly implemented to prevent people from bringing in garbage or dirt from the outside. If the operator's clothes or shoes have dirt, the dirt will also be brought into the production site, and in the lithium battery industry, dust, humidity, and temperature can have a great impact on product quality. Therefore, dressing neatly and wearing shoe covers are the minimum requirements. It takes a long time to pay attention to whether there is dirt on cleaning paper, labor gloves, waste filters, etc.

3. Keeping of the implementation

Because standardization is the maintenance of 3S results, it is actually a very difficult task. Companies keeps it up by using the following methods.

1) Carry out the company's 3S exchange meeting. The 5s team invites colleagues from other departments of the company to regularly organize visits and study, they can get inspiration or opinions on 3S.

2) Carry out the company's external observation meeting. The 5s team invites people from different departments of the company to visit, and the effect is remarkable. Similarly, if the team invites external personnel, including customers, suppliers, and reporters, to visit, employees will be greatly satisfied, proud, and motivated.

(3) Hold 5S related innovation meeting. Operators communicate with each other is a pleasant way to promote Standardization, it should also be noted that even if the method is improper, the leader should not too criticize, as that act might be counterproductive and reduce the enthusiasm and motivation of employees.

5.7 Sustain

For the sustain part, since this research follows the PDCA cycle, and some overlaps will be put in the later chapter, this section will mainly focus on the sustain training part of the implementation.

Sustain training program is as follows:

(1) Establish rules and regulations

When developing rules and regulations, pay attention to the comments of all employees, fully consider each employee's appeal, establish rules and regulations of the entire workshop. Such as: Welding Standard Operating Procedure (SOP), workshop staff dress standard, safety code, etc.

(2) visualization

The 5S team walks around the workshop and the visual board of the workshop, using red tagging, checking the important documents, and also use charts, board, cards, etc. to make each employee

can clearly understanding and consult the rules and regulations, the ultimate goal is to train the work habits of employees.

(3) Organize various training

Training for newly joined employees: 5S promoters and safety officers explain in detail for new employees to pay attention to various rules and regulations and safety precautions. Thus, new employees have a clear understanding of the rules of workshop profile and workshop 5s. The workshop's old employees should explain the background and significance of new employees to make new employees understand the reason. All teams use periodic 5S promotion meetings to summarize and train employees. The implementation of these measures is to make all employees of the workshop have a common understanding of 5S on-site management. Everyone has a common clear goal, and efforts have been made to reduce misunderstandings among employees.

(4) Violation of rules and regulations.

When seeing employees violate the workshop's rules and regulations, 5S promoters or team leaders must give them attention. At the same time, they should develop corrections and plans, regularly check them until the mistakes are completely corrected and thoroughly knows by operators.

(5) Emphasize the importance of 5S management in each meeting, regularly inspect employee's implementation. Promote employees to behave politeness, and it requires all employees to participate in activities such as regular improvement recommendations and reward for excellence.

5.8 Discussion

A STUDY OF THE CURRENT SITUATION AT BEYONDER AS

This chapter is for analyzing the status of the problem mentioned in the case description part of the thesis. All problems are categorized by the fishbone diagram as followed to be used as a reference while structuring the check sheets, which are need in the AHP analysis to define the current state of 5S management. Also, a general 5S check sheet that is well used in the production site has been made available for all employees. Five sheets are assigned specific to operators to give an overall score of the site status before the intended implementation. It let operators know how it should look like as an example, which would help them while joining the meeting to construct correspondent sheets from the 1S to the 5S.

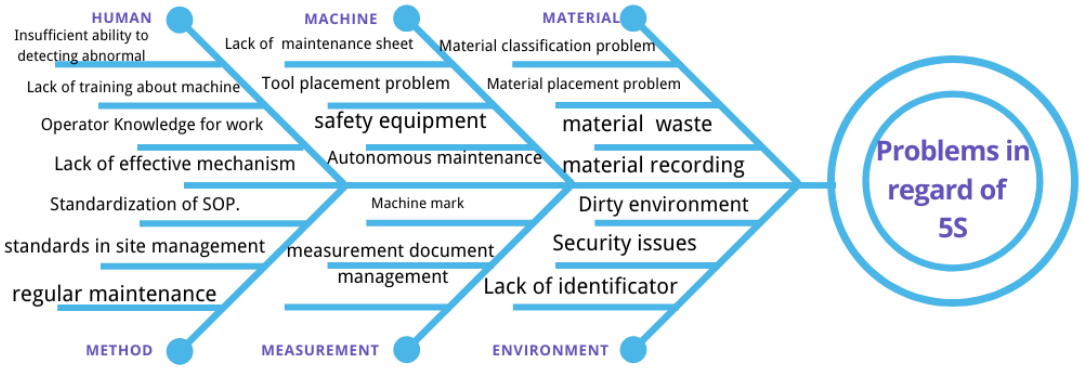

Figure 19. Fish Bone Chart for Problems

Analysis point of fish bone chart

a) Man / manpower: operator's understanding, technical proficiency, physical condition, etc.

b) Machine: The accuracy and maintenance status of machine equipment, engine clamps, etc.

c) Material: The composition, physical properties, and chemical properties of the material.

d): This includes processing, tooling selection, operational procedures, etc.

e) Measurement: Whether the method taken during measurement is standard and correct.

f) Environment (Environment) Working ground temperature, humidity, lighting, and cleaning conditions, etc.

Gradually, in the daily 5S meeting in the morning, with all the problems classified, a general 5S check sheet and 5 more specific subsidiary check sheets are developed for evaluation purpose. And

the 5S check sheet is carried on each Friday afternoon, 5 people are responsible for filling the sheet, and an average was calculated for the overall score at the date of the 5th of March, consisting of 1 engineer, 2 operators, 1 supply chain manager and the writer as the researcher.

Sort

Discuss the main points of Sort and check the results of the Sort to reduce the inventory of materials, semi-finished products or finished products, improve the utilization of storage facilities, reduce space waste, and create a clean working environment.

According to the company's actual situation, the following five inspection items were determined: aisle conditions, desks and workbenches, workplaces, warehouses, and racks. Each item is divided into five grades: excellent, good, passing, poor, and extremely poor, with the highest score for each item. The basic format of the score sheet for Sort is shown below.

Table 7. Sheet for Sort

Check Object	Check Item	Grading	Check Object	Check Item	Grading
Aisle	Too much item or dirty	1	Work area	Proper amount, while unsorted	4
	Must be careful	2		Proper amount, and sorted	5
	Some item in the aisle	3	Warehouse	Hard to go through	1
	Has items for short period of time	4		Items are randomly placed	2
	Clean and satisfied	5		No clear idea how much	3
Workbench	Items never been used	1		Category is not specific enough	4
	Too much Items that rarely been used	2		Things are sorted good	5
	Used recently, but too much	3	Rack	Items never been used	1
	Proper amount, while unsorted	4		Items are randomly sorted	2
	Proper amount, and sorted	5		No clear idea how much	3
Work area	Items never been used	1		Category is not specific enough	4

	Too much Items that rarely been used	2		Things are sorted good	5
	Used recently, but too much	3	Convert to 0-5 scale		

Set in order

According to the literature review chapter and the problems defined in this chapter, the 2S should make sure that the items are placed in suitable positions according to certain usage rules so that workers can easily find them. At the same time, the check sheet should be designed in a way that intend to make sure the designation of places for tools, machines, materials, in the workplace can avoid some unsafe behaviors and hidden dangers, making the entire work process more effective and safe, and improving the effectiveness of workplace.

Table 8. Sheet for Set in Order

Check Object	Check Item	Grading	Check Object	Check Item	Grading
Tool	Not positioned	1	Equipment	Reasonable positioning	4
	Too far away	2		Home after use	5
	Convenient place	3	Document	Discard files at will	1
	Place according to frequency of use	4		Arbitrary placement of files	2
	Return after use	5		File storage	3
Part	Unqualified products and qualified products are put together	1		Easy to retrieve	4
	Unqualified products are not processed in time	2		Reasonable positioning and easy to identify	5
	With location mark	3	Position mark	Most place lacking	1
	There are positioning signs and icons	4		Miss usage the tape type	2
	Return to position after use	5		Irregular	3
Equipment	Messy placement	1		Neat but unreasonable	4

	Placement	2		Neat and reasonable location	5
	Obvious equipment mark	3	Convert to 0-5 scale		

Shine

Based on the problems found and the actual situation, a form for evaluating Shine's results was made to ensure that the workplace and equipment can be clean, maintain a clean and bright environment, and maintain production safety. The current situation of the company has determined the following five inspection items, namely: desk, workbench, workplace, passage, doors and windows, dry room walls, the basic format of the score sheet is as follows.

Table 9. Sheet for Shine

Check Object	Check Item	Grading	Check Object	Check Item	Grading
Workbench	Tools, parts, documents are messy	1	Equipment	Relatively clean	4
	The worktable is covered with dust	2		Clean up in time, keep tidy	5
	The workbench is clean but broken	3	Aisle	Debris and graphite scratches	1
	Clean and tidy workbench	4		There are graphite scratches	2
	Clean and tidy around the workbench	5		Slightly dusty	3
Workshop	There are debris and other debris	1		Clean up in time	4
	Scratches on the ground	2		Clean regularly to keep it tidy	5
	Temporary dirt	3	Part	Scratched or broken	1
	Clean floor	4		There are slurry water stains	2
	The ground and the materials on the ground are clean	5		No water stains, but dust	3
Equipment	Rusty, noisy	1		part neat	4

	Dusty	2		Part is tidy and cleaned regularly	5
	Small amount of dust	3	Convert to 0-5 scale		

Standardize

According to the above-mentioned questions and actual situation, according to the different inspection objects, the following inspection items are determined daily activities, unnecessary items, methods of placing items, whether there is dust and garbage, and equipment-related inspection items. The formed sheet is shown below.

Table 10. Sheet for Standardize

Check Object	Check Item	Grading	Check Object	Check Item	Grading
Daily 3S activity	No activity	1	Position	There is a phenomenon of random placement, but it can be rectified in time	4
	Although there is general cleaning, but unplanned work	2		There are measures to prevent messing up and messing up	5
	Although there are 3S activities, but few and not timely	3	Dust and waste	There are dust, slurry, and other garbage	1
	Frequent activities	4		Dust and water stains on the ground	2
	Everyone actively participates in 3S activities	5		Clean regularly	3
For unnecessary item	There are garbage and unnecessary items	1		Dust and garbage can be cleaned up in time after they appear	4
	There are unnecessary items everywhere, but clean	2		There are measures to prevent dust and garbage from appearing	5
	There are unnecessary items, but the passage is clear	3	AM for machine	The equipment is running abnormal	1
	There are unnecessary items, but can be handled in time	4		Loose equipment bolts, leaking seals, lack of lubrication	2

	There are measures to prevent unnecessary objects from appearing	5		Pollution and danger can be treated from the source	3
Position	Place items everywhere	1		No phenomenon described above, but there are stains on the surface of the device	4
	Items are piled up randomly, but the aisles are clear	2		Daily inspection and cleaning according to regulations	5
	Arrangement of items in the fixed area is messy	3	Convert to 0-5 scale		

Sustain

For Sustain, we selected several items that can directly reflect the outlook and self-cultivation of employees for inspection, including code of conduct, employee appearance, clothing, time concept, daily behavior, etc. The checklist is shown in the table.

Table 11. Sheet for Sustain

Check Object	Check Item	Grading	Check Object	Check Item	Grading
Daily 5S activity	No activity	1	Outlook	Able to comply with the company's articles of incorporation	1
	Although there is a general cleaning, it is not a 5S job	2		Teamwork	2
	Promote 5S during the meeting	3		Dirty clothes	3
	There are 5S training, visits, and other activities	4		Partially untidy	4
	Everyone has improved about 5S	5		Buttons or shoelaces are not fastened	5
Manner and behavior	Neat appearance	1		Work clothes, identification card according to regulations	6

	The hair is tied up in the workshop	2		Dress according to regulations and be energetic	7
	One of the first two items is not well done	3	Punctual	Most people don't have a strong sense of time	1
	All sorted out according to regulations	4		Aware of time, but not on time at the beginning of work	2
	Full of energy	5		Aware of time, but not finishing work on time	3
	Behave rude	6		Have time awareness and will try to work on time	4
	Untidy clothes and unhygienic	7		Work will be done well in the appointed time	5
	Only do what is arranged, lack of cooperation	8	Convert to 0-5 scale		

When defining the key checkpoints, both problems are well-realized among employees, and what to put on the chart is carefully discussed in 5S meeting. This has provided valuable input for this research as in the later stage of this research, it not only helps in getting more information of the statues and the processes, but also in letting employees participate in such an event, which they will feel the sense of commitment, value their own effort that been made.

We evaluate the current situation of each area in accordance with the previous plan. By this time, one example room has already been built. We named it C2 room in the calculation; the die-cutting room and the coating room are named C1 and C3 separately. In this phase, the purpose is to use the example room as a reference, measure the current state, and measure what achievement had been done after the implementation stage.

Establish the judgment matrix of the criterion level and calculate its weights (Eigen Vector).
Level 1 to level 2, the weights (Eigen Vector).

Table 12. Calculate Eigen Value

	Sort	Set in order	Shine	Standardize	Sustain	priority vector
Sort	1	1/5	1/3	1/3	1/4	0

Set in order	5	1	4	4	3	0.462
Shine	3	1/4	1	1	1/3	0.117
Standardize	3	1/5	1	1	1/3	0.112
Sustain	4	1/3	3	3	1	0.254
Eigen value max=5.159			CI=0.04	CR=0.035		

Base on the theory of the AHP in previous chapter,
Calculate the rank vector

Table 13. Calculate Rank Vector

Sort	C1	C2	C3	Rank Vector	Sort	C1	C2	C3	Rank Vector	
C1	1	8	6	0.754	C1	1	1/7	1/5	0.072	
C2	1/8	1	1/4	0.065	C2	7	1	3	0.652	
C3	1/6	4	1	0.181	C3	5	1/3	1	0.278	
Eigen value max=3.136			CI=0.068	CR=0.117	Eigen value max=3.065			CI=0.032	CR=0.056	
Sort	C1	C2	C3	Rank Vector	Sort	C1	C2	C3	Rank Vector	
C1	1	6	8	0.754	C1	1	5	4	0.674	
C2	1/6	1	4	0.181	C2	1/5	1	1/3	0.101	
C3	1/8	1/4	1	0.065	C3	1/4	3	1	0.226	
Eigen value max=3.136			0.068	CR=0.117	Eigen value max=3.086			CI=0.043	CR=0.074	
Sort	C1	C2	C3	Rank Vector						
C1	1	1/2	1/2	0.2						
C2	2	1	1	0.4						

C3	2	1	1	0.4						
Eigen value max=3.000			CI=0.000	CR=0.000						

Then calculate the overall composite weight for C1,C2 and C3.

Equation 5. Matrix for Composite Weight

$$\mathbf{W} = \begin{pmatrix} 0.754 & 0.072 & 0.754 & 0.674 & 0.200 \\ 0.065 & 0.652 & 0.181 & 0.101 & 0.400 \\ 0.181 & 0.278 & 0.065 & 0.226 & 0.400 \end{pmatrix} \mathbf{x} (0.055, 0.462, 0.117, 0.112, 0.254)^T$$

$$= (0.289, 0.439, 0.272)$$

After calculating, the three numbers, 0.289, 0.439 and 0.272 stand for area C1, C2 and C3, separately. Those numbers indicate that the C2 mixing room area, with a 0.439 composite weight, is the best area out of three areas in terms of 5S specification. The result also shows that C1 room is slightly better than the C3 room, and they need to catch up with the C2 example room by following the proposed 5S steps, and the idea of PDCA methodology will guide the work.

This methodology will be used each time when the team wants to evaluate the areas regarding 5S implementation, and it's a valuable tool for knowing which area needs more work to be done.

6. Conclusion

6.1 Summary of achievement

6.1.1 Implementation Conclusion

This thesis answers two research objects, firstly, what needs to be done to fulfil 5S in the battery industry, Secondly, how to do it in practice. All the implementation conclusions, as well as knowledge learned from implementation, are listed below.

1. Before implementing 5s, it is needed to carefully understand the process and organizational structure, the company's logistics and management mode, and carefully look for the loopholes that demand improvement in the current site management.
2. In order to make 5S thoughts deeply imprinted in the minds of employees, the company should adopt a step-by-step model to train employees. Just like BEYONDER, it takes a step-by-step approach through 5S training to realize that each employee can be Resonate with 5S.
3. To draw up corresponding 5S plans for specific situations, and deal with the company's deficiencies in a targeted manner.
4. The key reason why BEYONDER has implemented 5S so smoothly is that they have dedicated coordinators for each link. From this point of view, if it is wanted to realize the 5S plan at high speed, an appropriate organizational structure is fundamental.
5. Objective and more practical goals are also crucial factors. The company is worth learning from other companies, that is, they have a thorough and realistic overall goal and direction at each stage.
6. In order to allow each unit to work more closely with 5S, BEYONDER applies the red tagging method to the production line. And it becomes clear that if a company wants to implement 5S successfully, it is not enough to only apply techniques but also needs to be combined with the production characteristics of the company. The measures taken by the BEYONDER company are appropriate, which has created the success of the BEYONDER company's operation. From experience gained in the company, it has a reference significance for other organizations.
7. In the process of 5S activities, it is inevitable that there was some resistance, which requires a certain degree of breakthrough and innovation in planning to avoid application failure.

8. The participation of all employees is the key to implementation, and the attention of the leaders is essential because all stages of the implementation of the work require the enterprise to invest the necessary resources, human, material, and financial resources, which requires the help of the leader

to provide these resources. In addition, the personal participation and coordination of the leader is a huge support for the promotion of the activity and a guarantee of success.

8. Pay attention to the study and summary of advanced management experience. In the case of discovering its own problems and not being able to solve them well, the company knows how to learn and learn from advanced management methods and then combine the actual practice of the company to practice and innovate advanced management methods.

9. Focusing on employee consciousness and creativity is an activity that requires the participation of all employees. Therefore, from the planning of the event, Beyonder focuses on the participation of all employees. From regular daily meetings to employees' scoring of the implementation, a series of activities are carried out, which enables 5s thinking to be gradually accepted by employees and finally transformed into their conscious actions.

10. Persistently carried out education, inspection, and evaluation from the first lesson of in-factory education, on-the-job training, Kanban and picture examples, daily cleaning and maintenance sheets, and regular inspections. Employees can be immersed in the 5s atmosphere all the time.

6.1.1 Improve work performance

Through the management of 5S, Beyonder will appropriately use all aspects (such as space, time, and resources) to maximize its effectiveness. The implementation of 5S has brought huge benefits to Beyonder, and the battery short circuit caused by dust has been reduced. By implementing 5S, the company can ensure a clean and tidy environment, better prevent dust from contaminating equipment or objects, always maintain the high performance of the equipment, and ensure the quality of production. Through the implementation of 5S, Beyonder realized that the quality of excellent employees can create good quality in a superior working environment, reduce the rate of defective products, and effectively increase the qualified rate of operation.

After the implementation of 5S, the company has gain huge benefits. For example, the layout of machines and materials is more reasonable, and the visual management is fully utilized. The hygiene of the production environment and workplace has been improved rapidly. Also, work efficiency and production quality have improved with the successful promotion of 5S. 5S activities have also effectively activated employees’ enthusiasm for work. Employees can spare no effort to complete their tasks, relying on 5S to bring a sense of accomplishment and fulfillment to employees. From this point of view, 5S guided employees to strengthen their awareness of

improvement. After the implementation of 5S, when a problem occurs on site, employees will actively and actively seek out the cause of the problem and try to solve it. At the same time, they can better develop the company. All this comes from 5S, which improves the quality of employees.

6.1.2 Issued problems

After implementation， employees are better educated and willing to detect abnormal and manage them, they are also more committed to their job. Raw materials that been placed irrationally now are organized in a systematic way.

Most of the things on-site, from machines to tools on shelves, are given specific fixed place and name labels, making things more traceable than before. Operators are getting hangs of each machine, cleaning and maintenance rules are standardized during this half-year process, and now they are hanging by the side of each machine with Standard Operation Procedure. Although the floor of the factory has some scratches, employees managed to keep it as clean as possible, which is required by the characteristic of the production of the battery cell. Document on-site is easier to find and to trace compare to 3 months ago. It should mention that managers are more focused on 5S, as it directly lowers the short circuit number of the stacking process, laid the needed foundation for this production site for further improvement.

6.2 Suggestions for further improvement

Inventory and ERP system

Currently, inventory is not well connected to production. The company tends to purchase a lot of safety stock to maintain the production flow, which leads to overloading of the warehouse to some degree and requires unnecessary effort to carry 5s in the warehouse. Ideally, with the help of an ERP system that enables enterprises to have a technology platform to realize the integration of value chain information, logistics and information flow can be carried out simultaneously. Managers can obtain inventory information at any time, and the management information will become more and more refined and integrated. In this way, when the production and sales information in the industry chain changes, the inventory manager can query the current inventory information in time, and

adjust the production and procurement business of the enterprise accordingly, and transmit the adjustment information in a timely and accurate manner to maximize the turnover rate of inventory.

Keep 5S achievement

With new machines installed on-site and new employees joining the company, it is essential to keep the same standard for all machines and train new employees. With the proper mindset initially, rather than gradually train them to merge into this working principle, 5s can be applied more smoothly following the circulating progressive of the PDCA implementation.

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