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Analysis of the Implementation of the Single Minute Exchange of Die Methodology in an Agroindustry through Action Research

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Abstract: This work aims to implement and analyze the effect of the Single Minute Exchange of Die (SMED) implementation in the bean packaging operation in a company in east Minas Gerais, Brazil. Design/Methodology/Approach: The research methodology used was action research. Two cycles of action research were conducted; the first to carry out phase one of SMED, and the second to execute phases two and three. Originality/Research gap: There are few studies on the application of Lean Manufacturing tools in agroindustry. Some works present case studies, mainly in the food supply chain aiming to fill this gap. Regarding SMED applied in agribusiness, no work was found. Key statistical results: The implementation of this methodology allowed the reduction of setup time by around 58%, the distance travelled by operators in the process by approximately 50%, in addition to gains in a production capacity of 14%. Practical Implications: It is concluded that the application of the methodology caused an increase in the company's productivity, as it was possible to obtain gains in productive capacity without changing the amount of hours worked or the number of employees involved in the production process. Limitations of the investigation: This methodology was applied only once and the challenges encountered were not documented.

Keywords: agroindustry; lean manufacturing; single minute exchange of die; action research; reduce setup time; productivity gain

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1. Introduction

The global market for dried beans (beans, peas, chickpeas, etc.) has been increasing, due to the awareness of their health benefits. In addition, as they are foods rich in micro nutrients, such as potassium, magnesium, folate, iron and zinc, they are considered important sources of protein in vegetarian diets [1].

Regarding the largest bean producers in the world, a survey carried out by The Food and Agriculture Organization (FAO) [2] between 2018 and 2020 indicates that Brazil, with 13% of world production, corresponds to the second-largest producer of this type of grain, behind only India [2], as shown in Table 1.

The high national potential for bean production, in addition to the recent rise in the domestic market, highlights the need to increase the productivity of industries related to this market.

Lean Manufacturing (LM) or Toyota Production System (TPS), according to [3], consists of a production system that aims at productivity gains and waste reduction. In the 90s, the LM principles were analyzed in more detail in the book "Lean Thinking" and, since then, its essence has been transferred from the efficiency of production to a certain type of organizational intervention and management focused on best practices and process improvement methodologies. In this way, efforts began to focus on increasing added value within the entire flow (from suppliers to end customers) and reducing waste in their processes [4].

Table 1. World bean production in tons from 2018 to 2020 [2].

Countries	2018	2019	2020	Average	Average %
India	6,220,000	5,310,000	5,460,000	5,663,333	25.46%
Brazil	2,916,365	2,908,075	3,053,012	2,953,243	13.28%
Myanmar	2,721,079	3,030,000	3,035,290	2,934,697	13.19%
China	1,324,407	1,322,508	1,281,586	1,309,500	5.89%
Tanzania	1,096,930	1,197,489	1,267,684	1,187,368	5.34%
U.S.A.	1,108,120	932,220	1,495,180	1,178,507	5.30%
Mexico	1,196,156	879,404	1,056,071	1,043,877	4.69%
Others	3,872,843	3,928,618	4,003,239	3,934,900	17.69%
Total	**22,706,612**	**21,461,027**	**22,669,231**	**22,278,957**	**100**

The number of LM implementations has grown and these have been found beyond the automotive sector (such as healthcare, construction, food processing) and various manufacturing processes (such as Product Development (PD), Supply Chain Management (SCM), accounting) [5]. Although agroindustry operates in a different context from small and medium-sized companies in which lean thinking is already applied, since 2010 there have been initiatives in countries such as Sweden, New Zealand and Japan to implement lean thinking in companies of this type of sector [6–8].

For LM to be fully introduced, the implementation of several tools is necessary, including the Single Minute Exchange of Die (SMED). SMED Setup is a set of activities that prepares a system for manufacturing a product, while setup time is the preparation period between the end of the last product made and the first product manufactured in the next process. Single-minute exchange of die (SMED) involves an installation performed in single-digit minutes (i.e., 9 min or less) [9]. References [9,10] states that the implementation of this tool allows for a series of improvements in the production system, such as productivity gains, reduction of stocks, gains in the flexibility of the production system and reduced lead time.

Shorter life cycles and highly customized products restrict the reach of the LM principles since they need changeability in production lines and laborious adjustments, buffer stocks and cycle times. However, the digital transformation and affordable hardware and software solutions promoted by the Industry 4.0 (I4.0) are allowing the boosting of LM tools using technologies such as RFID, cloud computing and sensors/actuators [11,12]. The systematic review in [13] contributes to the understanding of the junction between LM, I4.0 and manufacturing sustainability. The relationship between LP and I4.0 is explored by [14]. The proposed framework summarizes I4.0 technologies and LM practices in both directions. It helps understanding the requirements and effects of the application of I4.0/LM in a productive process. This allows the extension of concepts and practices to the agroindustry.

Therefore, considering LM and I4.0, there are two categories of work: (i) most of then are interested in a conceptual and theoretical discussion [13]; and (ii) those that focus on applications and case studies [14,15]. This work falls into the second category.

Additionally, the application of LM in the agroindustry has a literature gap. Some works such as [16–18] present case studies, aiming to fill this gap. Some research can be found in the food supply chain such as [19–22]. However, as discussed in [23], there is a lack of studies in this area, mainly in LM/SMED. The review presented in [9] points to action research methodology in various companies, improving sustainability and revisiting Shingo stages by monitoring and employee training [24].

This study addresses the implementation of the SMED tool in a company in eastern Minas Gerais, Brazil, that works with the processing, packaging, and distribution of beans. The packaging operation is the bottleneck in the process. It is what limits the company's production capacity. Therefore, this work aims to answer the following research problem: What is the effect of implementing SMED on the bean packaging operation in a company in east Minas Gerais, Brazil? Moreover, this work also try to answer: "can the LM/SMED tool be applied in a bean industry?" and, in a broader context, "can the use of LM empower agroindustry to Agro4.0?". A few studies have since been carried out in this context, our manuscript tries to fill these gaps by conducting an SMED in agroindustry through action research.

Thus, in terms of theoretical contribution, the relevance of this study is because although the international literature presents some work on the benefits of implementing SMED, there are few studies on its application in this type of company that consider the setup of a set of grain processing and packaging machines [9]. According to [25,26], sectors related to agriculture lack studies on the application of Lean Manufacturing and have the potential for developing the philosophy. In addition, this work also contributes with an empirical study on SMED in grain processing and packaging.

From the point of view of practical and managerial implications, all organizations that intend to implement SMED in a production line can benefit from this work, as the various aspects of SMED in operations management will be identified. Thus, knowledge of this information and encouragement to implement SMED in companies can help identify waste and consequently improve flexibility and add value to their production processes. The study of LM in this context also contributes to the dissemination of knowledge on the subject to current managers and professionals linked to the area of operation.

Concerning its relevance, the results of this research may contribute to the implementation of Lean in the Operation and thus create more opportunities for improvement so that companies can reach the status of excellence in operations. This work also contributes to the improvement of meeting the requirements of the market for bean packers and business strategies, as well as reducing costs and increasing the competitiveness in the market.

In addition to this Introduction, this manuscript is structured as follows. Section 2 provides the theoretical framework. Sections 3 and 4 describe the methodology and development, respectively. The results and discussions are carried out in Section 5. Finally, Section 6 presents the conclusion.

2. Theoretical Framework

2.1. Lean Manufacturing

Lean Manufacturing is a production system that emerged in Japan between the late 1940s and early 1950s, in the post-war period. Its birthplace was the Japanese company Toyota Motor Company and for this reason, it was first known as TPS—Toyota Production System [3,27,28]. TPS was developed exclusively by the Japanese, who wanted to create their own style of production, which would better suit their culture and surpass the conventional large-scale production system, producing a small amount of many different types of cars [3].

The production style was mainly due to two reasons: the first reason was the fact that the Japanese market, due to the context of the war in the 1930s, had a demand for small quantities of different types of cars and trucks, making large-scale production unfeasible [28].

The second reason was stated by the then president of Toyota, Kiichiro Toyoda, who in 1945 said that the Japanese auto industry had three years to reach the productivity of the US auto industry; otherwise, this branch of the Japanese industry would not survive [3]. Consequently, Toyota executives Eiji Toyoda and Taiichi Ohno, with the collaboration of Shingo Shingeo through consultancies, created a new production system in order to overcome the difficulties encountered in Japanese industry [28,29].

Ohno in [3] defines STP as "[...] a method to fully eliminate waste and increase productivity". In a production system, waste is related to every activity that generates costs without adding value to the product. In addition, the efforts to reduce waste also motivate the deployment of smart production systems by utilizing an autonomation policy [30,31].

The "TPS House" was developed in a way to explain TPS. The idea of representing TPS through a house occurred because a house can only remain stable if the foundation, pillars, and roof are strong and well connected [27]. According to [27], the roof represents the goals of this system, which are to improve quality, reduce costs and lead time. The foundation is composed of processes that guarantee the stability of the system, such as level production (heijunka), stable and standardized processes, visual management, and the Toyota Model philosophy.

The pillars that support this system are just-in-time (JIT) and production automation with a human touch or autonomation [30,31]. JIT means that the correct material will reach the assembly line of a flow process at the right time and in the right amount. On the other hand, automation with a human touch, unlike conventional automation, allows machines to automatically stop the production line whenever they identify a problem, using devices capable of identifying product failures. These pillars enabled the large-scale reduction of waste found in conventional car production [3].

As Toyota made greater profits than other companies did, even in times of crisis, the interest of researchers and other Japanese companies in this Toyota production model increased. TPS began to be studied and the ideas of this productive system began to be disseminated throughout the world. With the publication of the first edition of the book "The Machine that Changed the World" in 1990, TPS also became known as Lean Production or Lean Manufacturing [3,28].

According to [28], the researcher at the International Automotive Vehicles Program (IMVP), John Krafcik, explained why this production system is called "lean":

> *[...] by using smaller amounts of everything compared to mass production: half the factory worker effort, half the manufacturing effort, half the tooling investment, and half the planning hours to develop new products in half the time. It also requires far less than half of the current inventories at the manufacturing site, results in far fewer defects, and produces an ever-increasing range of products.*

The total elimination of waste, that is, the elimination of activities that do not add value and generate costs, allows companies to reduce the efforts necessary to produce their products and consequently increase the efficiency of the production system and reduce costs [3,28]. The LM aims to produce products and services at the lowest cost and as fast as required by the customer [32].

LM concepts have been widely disseminated and studied throughout the world. Recently, this concept was expanded outside the production systems of factories, being called Lean Thinking. According to [28], "lean thinking is a way of specifying value, aligning the actions that create value in the best sequence, carrying out these activities without interruption whenever someone requests them and carrying them out in an increasingly effective way".

2.1.1. Waste and Value

Waste and value are two key concepts of Lean. As discussed in [33] seven or eight wastes are identified in the literature as well as the concept of waste as an activity that does not add value; defining waste, in general, as any input to the system that is not transformed into an output that represents value to the customer (customer satisfaction), at the right time and amount (just-in-time). As for the concept of value, Ref. [28] stated that value is something that can only be decided by the end customer, being expressed in a relevant way only when it comes to a particular product, whether it is a good, a service or both, which meets the needs of the end customer at a given time and at a specific price. It indicates that the value can be determined by what the customer is willing to pay.

2.1.2. The Eight Types of Waste

Taiichi Ohno was the pioneer in recognizing the existence of waste in production systems, as well as the one who dedicated himself to eliminating it. Ref. [3] states that the shop floor is the best source of manufacturing information, providing up-to-date and direct information about the management. In addition, it is where you can identify the waste present in manufacturing. Ref. [27] states that Toyota first identified seven wastes in production, but the author includes an eighth type of waste (Figure 1):

1. Defect: the production of defective items or the reprocessing of defective items, which generally result in wasted time and effort;
2. Overproduction: the production of items excessively, exceeding demand;
3. Wait: the time when the worker and machine are idle;
4. Non-utilized talent: the waste of employees' time, ideas and skills;
5. Transport or unnecessary motion: the movement of materials excessively or inefficiently;
6. Inventory: inventory that is larger than necessary, causing additional costs related to excessive transport and storage, obsolescence, damaged products, and longer lead times;
7. Motion: the movement of an employee, during work, to carry out activities that do not add value and are unnecessary;
8. Extra-processing or incorrect processing: processing too much of an item.

Figure 1. The eight types of wastes.

2.2. Quick Changeover

First, it is necessary to define a concept that will be broadly covered in this work, the concept of machine setup time, also known as setup. According to [34], setup is the change in production to manufacture another product in a machine, or in a sequence of interconnected machines, through the exchange of parts, dies, devices, molds, among others. Setup time is the time elapsed between the production of the last item of the completed cycle and the first item, of quality, of the cycle that has just been started.

SMED, also known as quick changeover, is a concept developed by Shigeo Shingo between 1950 and 1969 to reduce machine setup time. It consists of a methodology with the objective of reducing setup time to single digit minutes. In this way, it is possible to reduce setup times from several hours to less than 10 min [29,35–37].

SMED was developed to solve one of the biggest problems faced by companies: to produce in a diversified manner and in small batches. Believing that it was impossible to reduce setup times drastically, line managers were for a long time forced to adopt low-diversity and large-batch production to minimize the effect of machine setup time on production capacity. However, large-scale production contributes to the waste of overproduction, which leads to an increase in stock and consequently generates additional costs [29,37].

Reducing setup time was the strategy that enabled diversified production in small batches, without loss of production capacity, enabling a significant reduction in stocks [10,35,37].

In addition to the reduction in machine setup time, Ref. [10] highlights several positive effects of adopting the SMED methodology. The main ones are the improvement of production capacity and machine utilization rates, production without stocks, elimination of errors in the setup process, improved quality of products, improved safety in the setup process, improved organization of the tools needed in the setup process, motivation in relation to the occurrence of setup, reducing the necessary qualification of the operator who performs the setup and improvement of production flexibility.

2.3. SMED Implementation Steps

While conducting studies to reduce setup times, Ref. [29] realized that machine setup operations could be divided into two—internal setup and external setup. According to [10], the internal setup or internal setup time (IST) consists of the machine setup operations, which can only be performed while the machine is stopped. On the other hand, the external setup or external setup time (EST), according to the author, consists of the setup operations of the machines that can be performed while the machine is running. The stages of the SMED implementation process, according to [10], are divided into four:

- Initial phase: Setup time is not divided into internal setup and external setup;
- Stage 1: Setup division into internal setup and external setup;
- Stage 2: Transformation of internal setup into external setup;
- Stage 3: Simplification of internal setup and external setup operations.

The initial stage is the step in which the methodology implementation planning takes place. At this stage, a study of the current conditions of the setup process is carried out, identifying all activities and the time spent on each one of them and the displacement of operators [10,35].

Stage 1 is the step in which IST and EST are differentiated, which represents the most important point of the methodology. This stage ensures that activities that may take place while the machine is still running actually take place while the machine is still on. The focus of this stage is the activities related to the setup and functional verification of raw materials, tools, and fastening devices that must be performed while the machine is still on [10,35,36].

Stage 2, on the other hand, is a stage in which internal setup activities are converted, when possible, into external setup, minimizing the number of operations that are performed while the machine is not in operation [10,36].

Finally, Stage 3 is the stage in which the activities of internal setup and external setup are simplified as much as possible, with the objective of increasing the ease, security, and speed of setup. Setup activities are modified in order to make them faster and can reduce the workload. EST can be simplified, mainly through improvements in the storage and transport of the elements necessary for the machine setup process. IST, on the other hand, can be simplified through the implementation of parallel operations, the use of functional fixators, and the elimination of adjustments [10,36].

3. Methodology

The research method used in this study was action research. According to [38], action research consists of a scientific research methodology that can be used to solve social or organizational problems, with the participation of people who live with this problem, through actions in the object of study. The steps required to implement this research methodology are shown in Figure 2.

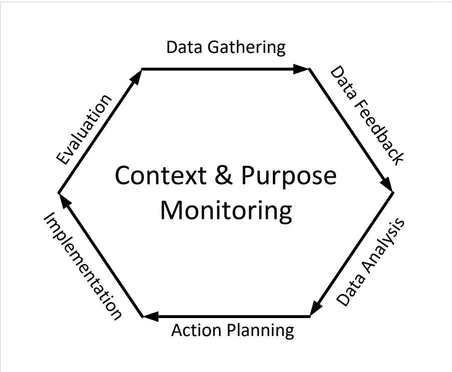

Figure 2. Steps for implementing action research (Adapted from [38]).

This research method was chosen because it is intended to make changes to the object of study. The authors plan to carry out the action research cycle twice. The first cycle to perform stage 1 of SMED, separating the internal setup from the external setup. The second cycle to execute stages 2 and 3 of SMED, transforming the internal setup into an external setup and simplifying the setup operations.

4. Development

4.1. Context and Proposal

The object of study of this work is a medium-sized company located in east Minas Gerais, Brazil. Its main activity is the processing, packaging, and distribution of beans, in addition to the distribution of rice and cassava flour. The main product sold by the company is carioca beans. The company also works with other varieties, black and red beans. The flow of operations of the processing and packaging of beans throughout the production process is shown in Figure 3.

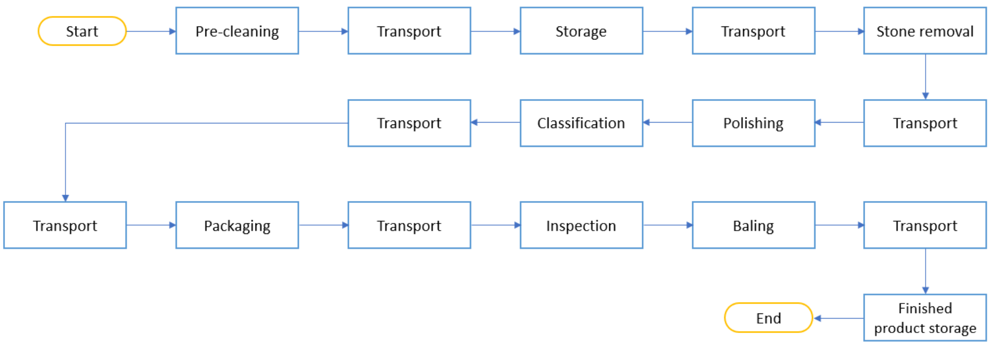

Figure 3. Flowchart of bean processing and packaging process.

After unloading the beans, the processing begins. In the operations of the processing, impurities from the harvest are removed, such as straw, clods, stones, and dust. In addition, bean husks and broken beans are also removed. All transport carried out in the processing is carried out by bucket elevators. The packing process, on the other hand, consists of bean packing and baling operations. In the packaging, the beans are packed in 1 kg packages. In the baling, these packages are again wrapped in 10 kg or 30 kg bales.

For the implementation of SMED, the setup chosen was the changeover of the 30 kg bale of red beans for the 10 kg bale of carioca beans. This setup was chosen because it is the most complete performed by the company since the improvements obtained in this process of setting up the machines can be used in all other setups of the packaging operation. In addition to the complete setup, the partial setup and the basic setup are also performed in this operation.

The complete setup consists of activities in the processing, packaging, and baling operations. The processing operator cleans all the machinery in this process to avoid mixing beans of different varieties. The packaging/processing operator, with the help of the repairperson, replaces the primary and secondary packaging, in addition to changing the baler die. The partial setup consists of the same actions in the processing and the replacement of primary packaging in the packaging operation. While the basic setup only consists of replacing the primary packaging in the packaging operation.

For the implementation of SMED, a team composed of four members was first assembled, with specific functions to monitor and map the execution of the setup. These members are: the observer, who is responsible for observing and recording the activities of the operators; the timekeeper, who is responsible for taking the time for each activity; the shadow, who has the function of recording the route and the number of steps of operators; and the Kaizen man, who has the function of identifying points of improvement in the execution of the setup.

In order to map the setup in the initial phase, the team filmed the setup of the machines to raise all the necessary steps for the implementation. Once the implementation steps were defined, the first data collection was carried out.

Through the obtained data, it could be verified that there were 84 activities necessary for carrying out the machine setup. Of these 84 activities, 15 were identified as external setup, as they could be performed while the machinery was still in operation. In addition, the total time for carrying out the activities corresponds to approximately 85 min.

In the data collection, the distance travelled by the operators was also measured through the number of steps, as well as the path travelled by the operators in the production system. The path was illustrated by the spaghetti diagram shown in Figure 4.

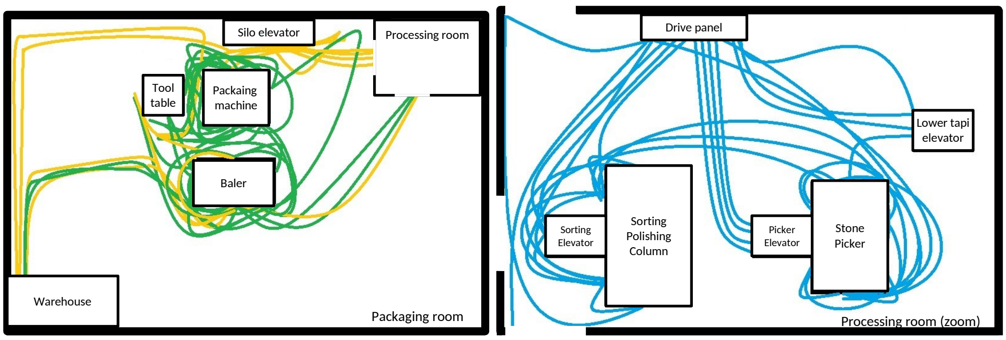

Figure 4. Spaghetti diagram of setup in the initial phase. Each color represents a different operator.

During the machine setup, the operator responsible for processing, shown in blue, covered 448 steps. In this work, each step of the operator was considered equivalent to 60 cm, so the processing operator covered about 269 m. The operator responsible for the packaging and baling operations, represented in green, travelled about 453 m. Finally, the repairperson, represented in yellow, moved approximately 143 m.

4.2. First Cycle of Action Research

From the first data collection, besides the analysis and classification of machine setup activities between external and internal setup, the time of use of the repairperson during machine adjustments was also observed in order to increase its participation in the process. The activities classified as EST started to be performed while the machinery was in operation. Furthermore, these activities, which were previously dependent on the operator, are now performed only by the repairperson.

Based on these setup changes, a new data collection was performed to assess the effect of EST elimination on setup time. With the elimination of external setup activities, the number of activities performed during the machine setup period dropped to 69 activities; in addition, the execution time was reduced to about 60 min, representing a reduction of approximately 30% compared to the previous time. The paths taken by the operators and the repairperson during the execution of setup underwent changes with the absence of activities considered EST. In general, there was a reduction in the path of operators, as shown in Figure 5.

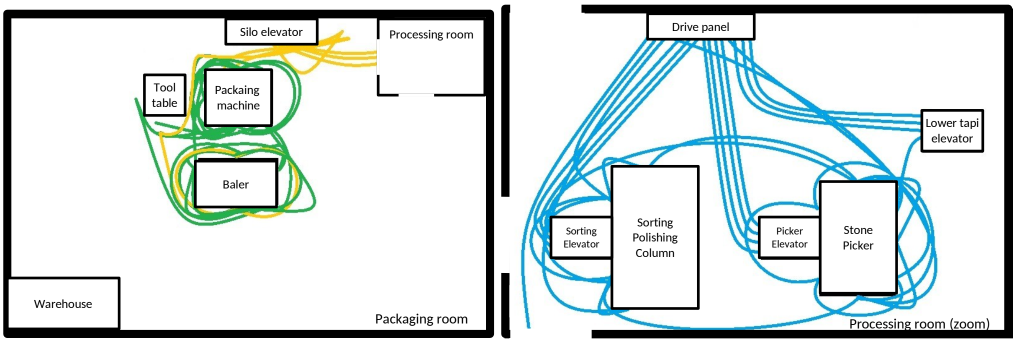

Figure 5. Spaghetti diagram of setup after cycle 1. Each color represents a different operator.

With the reduction in the number of activities during the machine setup process, the operator responsible for the improvement process, shown in blue, started to cover approximately 194 m. The operator of the packaging and baling operations, in green, and the repairperson, in yellow, moved approximately 250 and 51 m, respectively. Table 2 summarizes the results obtained with the implementation of the first cycle of action research.

Table 2. Summary of the first cycle of action research.

Data collection	List and timing of activities: - Internal Setup = 85 min - External Setup = 0 min Travelled distance: - Processing: Operator = 269 m - Packaging/Balling: Operator = 453 m Repairperson = 143 m
Data Analysis	Classification of setup activities into internal setup and external setup; Repairperson usage time.
Implementation	Separation of the internal and external setup in the execution of the setup; Redefining the activities of operators; Redistribution of external setup activities to the repairperson.
Evaluation	Measurement of the new setup method: - Internal Setup = 60 min - External Setup = 25 min Travelled distance: - Processing: Operator = 194 m - Packaging/baling: Operator = 250 m Repairperson= 51 m

4.3. Second Cycle of Action Research

Based on the information obtained in the data collection of the first action research cycle, an analysis was carried out to identify improvements in the IST activities, unnecessary activities, the feasibility of using more employees, improvements in the sequence of activities, opportunities for error reduction, layout improvement, and opportunities to reduce adjustment time and the number and size of screws removed during setup.

Based on data analysis, an action plan was developed using the 5W2H tool in order to obtain not only a reduction in setup time but also a reduction in the occurrence of errors, gains in product quality, and gains in the organization of tools needed. The action plan is detailed in Table 3.

Table 3. Action Plan.

What to Do? (What)	Why Do It? (Why)	How to Do It? (How)	When to Do It? (When)	Where to Do? (Where)	Who Is Going to Do? (Who)	How Much Does It Cost? (How Much)
Use the ratchet wrench for installation and removal of screws	To reduce the necessary adjustment time	Through the purchase of the ratchet wrench and operator training	September/October	In the baler	Packaging/Balling Operator	BRL 160.00
Reduce from 4 to 3 different screw sizes	To reduce the necessary adjustment time	By replacing the 13 mm drive belt screws with 14 mm screws	September/October	In the baler	Third-party company	BRL 100.00
Use a method to simplify installation of screws	To reduce the necessary adjustment time	By using a method that already existed in the baling die but which was unknown to employees	September/October	In the baler	Packaging/Balling Operator	BRL 0.00
Install compressed air in the packaging silo	To improve the quality of cleaning of the packaging silo, which was performed with a piassava broom since pieces of piassava can contaminate the product about to be packaged	By purchasing and installing the necessary materials	September/October	In the baler	Packing/baling coordinator and operator	BRL 50.00
Implement 5S on the tool table	To improve the organization of tools and reduce the time wasted in finding them	Through the application of the 5 senses of this methodology	September/October	Tool table	Researcher, coordinator and operator of the packaging/baling	BRL 0.00
Introduce a new repairperson and a new operator into the setup process	To share the necessary activities with more employees, reducing setup time and necessary displacement	Through training	September/October	In the processing and packaging sectors	Researcher, coordinator, operators, and assistants	BRL 0.00
Reorganization of setup activities	So that the setup in the packaging sector can start simultaneously with the setup in the processing sector	Through the redistribution of activities with the new employees involved in the setup	September/October	In the processing and packaging sectors	Researcher, director, coordinator, operators and assistants	BRL 0.00
Create a new standardized work sequence	To optimize the time needed to run the setup and avoid errors and rework	Through meetings and discussions	September/October	In the processing and packaging sectors	Researcher, director, coordinator, operators and assistants	BRL 0.00

The method to simplify the installation of the screws is to place slots in two holes of the baling die; this allows the installation of two screws before positioning this die in the baler. In addition, there were two screws of similar sizes (13 and 14 mm), which allowed the reduction from four to three different screw sizes by enlarging the smaller holes. Finally, a ratchet wrench was purchased for the installation and removal of the screws, which reduced the time for adjustments.

A new operator and a new repairperson were introduced to participate in the setup since there were already employees available to perform the activities (they used to perform activities with lower priority). The new operator was responsible for the activities of the packaging operation, allowing the former operator to carry out only the activities of the baling operation. The former repairperson started to help both the processing operator and the packaging operator. The new repairperson was responsible for part of the activities related to the processing.

Through the introduction of new employees in the setup, it was possible to reorganize the machine setup activities. This reorganization of activities allowed the actions related to the processing, the packaging operation, and the baling operation, which were previously carried out in sequence, to be started in parallel. With all these setup changes, a new standardized work sequence was developed. The standardization of this new work sequence contributes to the elimination of errors that could occur during the setup of the machines.

In order to assess the effect of the proposed improvements to the setup, set out in the action plan, a new data collection was carried out. With the changes proposed in the action plan, the setup time was reduced to approximately 36 min, which corresponds to the setup time of the baling operation activities, as it is the procedure that demands the most time of the entire setup operations. This reduction in setup time corresponds to around 40% in relation to the time obtained after the first cycle of the action research, and a reduction of around 58% in relation to the initial setup time.

As for the path taken by employees, there was a reduction in the path travelled and the distance travelled, mainly due to the introduction of the new operator and the new repairperson. The path taken by operators and repair people is illustrated in Figure 6.

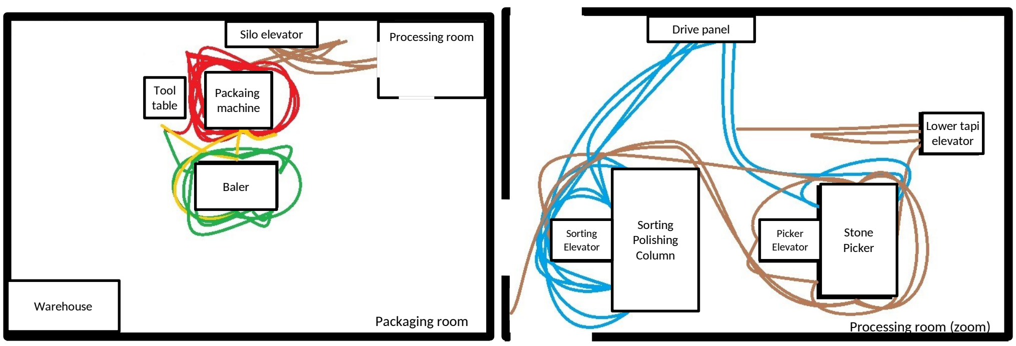

Figure 6. Spaghetti diagram of setup after cycle 2. Each color represents a different operator.

At the end of the second cycle of the action research, the processing operator, represented in blue, started to walk approximately 60 m, while the new repairperson, represented in brown, covered approximately 102 m. As for the new operator of the packaging operation, represented in red, and the operator of the baling operation, represented in green, they moved approximately 63 and 172 m, respectively. Finally, the repairperson for the packaging and baling operations, represented in yellow, started to travel approximately 35 m.

Table 4 summarizes the results obtained with the implementation of the first cycle of action research.

Table 4. Summary of the second cycle of action research.

Data collection	New setup method: - Internal Setup = 60 min - External Setup = 25 min Installation and removal of screws: - Number of screws: 14 screws Different sizes of screws: 4 sizes Distance travelled by operators: - Processing: Operator = 194 m - Packaging: Operator = 250 m Repairperson = 51 m
Data Analysis	Improvements in internal setup activities; Identification of unnecessary activities; Feasibility of using more employees; Improvements in the sequence of activities; Opportunities to reduce errors during machine setup; Improved layout; Number and size of screws removed during setup; Opportunities to reduce adjustment time.
Implementation	Acquisition of a ratchet key; Reduction from 4 to 3 different screw sizes; Using a method to simplify the installation of the baling die screw; 5S Implementation on the tool table; Installation of compressed air for cleaning the packaging silo; Introduction and training of a new repairperson and a new operator in the setup process; Reorganization of setup activities; Creation and implementation of a standardized work sequence;
Evaluation	Measurement of the new setup method: - Internal Setup = 36 min - External Setup = 25 min Travelled distance: - Processing: Operator = 60 m Repairperson = 102 metros - Packaging/processing: Packing operator = 63 m Processing operator = 172 m Repairperson = 35 metros Installation and removal of screws: - Number of screws: 14 screws - Different sizes of screws: 3 sizes

5. Results and Discussions

Both action research cycles carried out strongly contributed to the reduction of the necessary setup time, in addition to also reducing the displacement of the employees involved. Consequently, the reduction in the setup time of the machines contributed to the increase in the company's production capacity since part of the time required by the setup became available for production.

It is important to highlight that the improvement actions performed for the most complete setup also had a positive effect on the execution time of the partial setup and the basic setup, mentioned above.

Productive capacity gains, as well as the effect of complete setup improvements on partial and basic setup, are described in Table 5. At the end of each action-research cycle, there were reductions in setup time and employee displacement, in addition to an increase in the company's production capacity. The result obtained in each cycle is described in Figure 7.

As shown in Figure 7, at the end of the second cycle of the action research, setup time was reduced by approximately 58%, the displacement of employees, even with the increase from three to five employees, was reduced by around 50%. The productive capacity had an increase of approximately 14%. During the implementation of SMED, operators initially resisted, as they believed the changes would entail a greater workload. However, as the methodology was implemented, operators began to realize the benefits brought by SMED and that there would not be an increase in work. From that moment on, they started to support the changes brought about by the methodology.

Table 5. Effect of setup improvements on production capacity.

First Cycle of Action Research	
Effect on setup time	- Complete Setup: −30% Average setup/month: 2 - Partial Setup: −38% Average setup/month: 32 - Basic Setup: −45% Average setup/month: 23
Effect on monthly productive capacity	- Operational availability (2 × 25 min) + (32 × 16.32 min) + + (23 × 5.37 min) = 695.52 min/month - Capacity increase: approximately 32,661 kg of beans/month (9.33%) - Prior productive capacity: approx. 350,000 kg of beans/month - Production capacity afterward: approximately 382,661 kg of beans/month
Second Cycle of Action Research	
Effect on setup time	- Complete Setup: −40% Average setup/month: 2 - Partial Setup: −32% Average setup/month: 32 - Basic Setup: 0% Average setup/month: 23
Effect on monthly productive capacity	- Operational availability (2 × 23.23 min) + (32 × 8.42 min) + + (23 × 0 min) = 315.26 min/month - Approximately 14,823 kg of beans/month (3.87%) - Approximately 382,661 kg of beans/month - Production capacity afterward: approximately 397,484 kg of beans/month

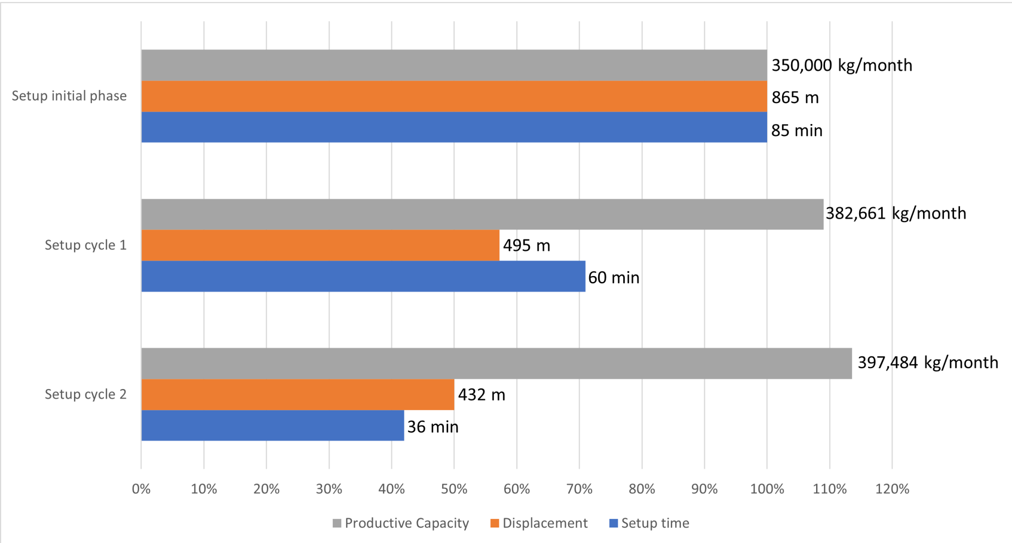

Figure 7. Result at the end of each action research cycle.

6. Conclusions

This work aimed to evaluate the effect of SMED implementation in the bean packaging operation in a company in eastern Minas Gerais, Brazil. With the implementation of this methodology, it was possible to obtain a reduction in setup time and, consequently, there was an increase in the company's productive capacity, in addition to a reduction in the displacement of employees. As for the increase in the productive capacity, there was no change in the workforce or working hours, so it can be concluded that the company achieved productivity gains.

In addition to the increase in productivity, quality gain, gains in the organization of tools, and the reduction in the occurrence of errors mentioned above, SMED also had the advantages of increased motivation regarding the occurrence of setup and increased production flexibility, as the effect of set-up time on production capacity has been reduced, allowing machine set-up to take place more times a day if necessary.

Finally, for the implementation of SMED, there was full support and encouragement from the company's management, which was already looking for alternatives that could expand the company's production capacity. Management was satisfied with the results obtained, mainly due to the low investment (approximately BRL 310.00).

In terms of a theoretical contribution, this work is one of the few studies that deal with the implementation of SMED in a company in the grain processing and packaging sector, showing the possible results obtained by the methodology and confirming its effectiveness in reducing setup time. This study shows that the LM/SMED tool can be applied in a bean industry and LM can empower the agroindustry to Agro4.0. Few studies have been carried out in this context, so our manuscript tries to fill these gaps by conducting an SMED in agroindustry through action research.

In terms of practical contribution and relevance to the sector, despite the little interaction of Lean tools with companies in this segment, this study showed that SMED proved to be an effective option for obtaining gains in productive capacity by reducing setup time, opening doors for new studies on the implementation of other Lean Manufacturing methodologies, such as line balancing and time planning.

As a limitation of the study, it is possible to highlight that the methodology was applied only once. The findings were also not fully documented. So, there is still room for improvement in the research method.

As future work, the relationship between LP and I4.0 and Agro4.0 can be explored. Practical applications including process-related systems and technologies of I4.0 [12], combined with scientific methodology, are an opportunity to fill the existing literature gap in the area.

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