Waste Minimization in a Concrete Block Company Using Lean Six Sigma, ECRS, and TRIZ Methods

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Abstract

This study aims to identify critical waste, find the causative factor, and make recommendations for improvements to critical waste that causes poor productivity in the company. To achieve this goal, the Lean Six Sigma, Eliminate, Combine, Rearrange, and Simplify (ECRS), and Theory of Inventive Problem (called TRIZ) methods will be applied to find non-value-added activities and provide improvement solutions to minimize critical waste. In the define stage, for Value Stream Mapping and identification of critical waste, the measurement stage looks for the DPMO value, Sigma level, and process capability. Then, the analysis stage analyzes the root causes of critical waste using 5-whys, and the improvement stage applies ECRS, TRIZ, and 5S. The results showed that defect waste was a critical waste (25%), DPMO 13128.75, the company's Sigma level was at 3.7, and the process capability was 1.23. The 5-whys results show that: there is no means of transportation to replace employees, no formal quality standard, lack of awareness of health & safety, and immature mortar. The solution for minimizing waste defects is the need to conduct training and evaluate the implementation of the SOP. Carry out production floor cleaning. Install CCTV in the mixer to avoid re-mixing, adjusting the quality standards, requiring Concrete Block transportation equipment with better automation level.

Keywords:
Eliminate, Combine, Rearrange, and Simplify (ECRS), Lean Six Sigma, Theory of Inventive Problem (TRIZ), Waste, 5S

1. Introduction
In today's competitive business world, companies that can survive can adapt to the business environment so that it avoids problems that come at any time. One of the causes of the problem is the lack of productivity which causes competitiveness (Aparicio et al., 2016). The problem of productivity is one of the complex problems faced by organizations. Productivity measures the ratio between inputs responsibly to produce outputs that are beneficial to consumers or users. Productivity is an essential measure in manufacturing operations and turnover and profit, as it provides insight into the efficiency and effectiveness of operations. Productivity is also referred to as the effectiveness and efficiency that companies use to convert inputs into outputs: a measure of the effectiveness and efficiency of an organization in producing outputs with available resources. Productivity is the ratio of two scalars, aggregate output and aggregate input (Aparicio et al., 2016).

The Cidade Block Building Industry (CBBI) company has engaged in the Concrete Block industry since 2011 in Dili, Timor Leste. The field study results identified that the CBBI company still faces several problems, such as inappropriate products, many defective products, too much idle time, and not achieving the company's targets. This wasteful activity is more time-consuming, causing overtime in the production process to increase and reduce the output of the Concrete Block produced. Control of the production process is crucial to minimize waste that results in company productivity. Thus, this study aims to identify waste in the concrete block production process, find the factors causing critical waste, and make recommendations for improvements to critical waste that causes poor productivity in the company. To achieve this goal, the Lean Six Sigma, ECRS, and TRIZ methods will be applied to find non-value-added activities and provide improvement solutions to minimize critical waste.

Several previous studies conducted using the Lean Six Sigma method, such as research conducted by (Burawa, 2019), on Carton Manufacturing Industry (Burawat, 2019), researched productivity improvement Highway Engineering Industry. In addition, Indrawati & Ridwansyah (2015) also researched An Iron Ores Industry on Manufacturing Continuous Improvement and Rafsanjani and Singgih (2018) researched Quality Control and Improvement of Product Packaging Printing Process. Some of the studies mentioned above use the lean six sigma method with others in solving problems, but no research has tried to combine the Lean Six Sigma, ECRS, and TRIZ methods in solving complex problems in the company. Thus, researchers want to combine the Lean Six Sigma, ECRS, and TRIZ methods to solve problems significantly to minimize the waste faced by brick companies. Combining Lean Six Sigma, ECRS, and TRIZ makes it possible to maximize solving waste problems rather than using only one method or using it separately.

Lean Six Sigma is a methodology to increase shareholder value by improving customer satisfaction, cost, quality, process speed, and investment capital (George, 2002). In addition, lean is a method to eliminate waste caused by defects, overproduction, waiting, transportation, inventory, motion, excess processing so that lean can help minimize non-value-added activities in the Concrete Block production process. Lean Six Sigma is also a process of all continuous improvements, such as delays and defects that always occur in the company's production activities. The Lean Six Sigma improvement process includes the Define, Measure, Analyze, Improve, Control (DMAIC) stages. In addition, the Eliminate, Combine, Rearrange, and Simplify (ECRS) method is an improvement method that can help minimize waste. Moreover, TRIZ is an improvement method that defines technical problems to solve problems for which the possible steps in the solution are unknown (non-routine problems) (Nurkertamanda and Ahman, 2010).

2. Literature Review

2.1 Lean Six Sigma

Lean Six Sigma is an improvement methodology invented in the late 1990s and early 2000s, i.e., integrating Lean and Six Sigma methods. Lean and Six Sigma are complement or cover the weaknesses of the two methods (Burawat, 2019). Lean manufacturing is used to eliminate/reduce waste in the company but cannot reduce process variations, while Six Sigma can reduce process variations but cannot reduce losses or production time. Therefore, these two concepts are applied together, Lean Six Sigma, which aims to eliminate losses in the production process and use statistical principles to reduce variations in the production process. Besides that, Rafsanjani and Singgih (2018) used Six Sigma as a reference for the improvement process by using the Define, Measure, Analyze, Improve, Control (DMAIC) flow stages in their research. The DMAIC upgrade cycle is a core tool and is used as a framework for any repair application**.**

The completion of one cycle continues with the beginning of the next cycle. The DMAIC cycle consists of five successive steps or phases. First, define (define) (D) is the business problem, objectives, potential resources, project scope, and high-level project timeline. This information is the project charter document. He writes down what is currently by clarifying the truth, setting goals, and forming a project team. Second, measure step (M) aims to establish the current baseline objectively as the basis for improvement. The second step is a data collection step, which aims to establish a baseline for process performance. Third, analyze (A) aims to identify, validate, and select the root cause of elimination. Fourth, improvement (I) aims to identify, test, and implement solutions to the problem, in part or whole. The improvements depend on the situation, for example, identifying creative solutions to eliminate root causes to fix and prevent process problems. Finally, control (C) ensures sustainability by making a change stick. Once the solution resolves the problem, improvements should be standardized and continuous (Burawat, 2019). Figure 1 shows the purpose of Lean Six Sigma's improvement.

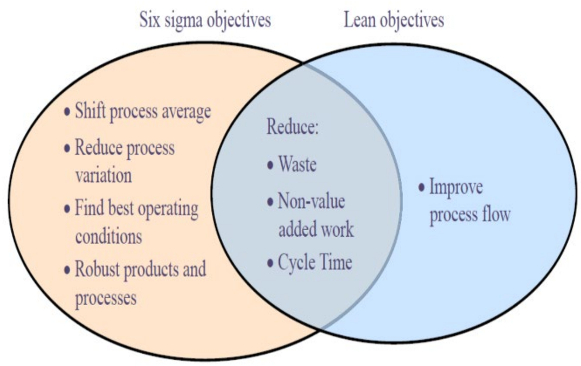

Figure 1. Improvement Objectives
Source: (Snee, 2010)

2.2 *Value Stream Mapping* (VSM)

Value Stream Mapping (VSM) is a material and information flow mapping that will cover all activities during the manufacturing process (Zahraee et al., 2020). Value Stream Mapping (VSM) can also be used in mass production systems to predict the volume and type of repetitive products (Mudgal et al., 2020). Value Stream Mapping (VSM) can also provide a clear and concise communication flow between management and the team on the ground about lean expectations, along with the actual flow of materials and information.

2.3 *Seri, Seiton, Seiso, Seiketsu,* dan *Shitsuke* (5S)

5S stands for five Japanese words, including Seri, Seiton, Seiso, Seiketsu, and Shitsuke. This 5S philosophy developed in the 1980s in Japan. This tool analyzes work processes and improvements to create and maintain a well-organized, clean, effective, and high-quality workplace. 5S practices have proven to be a significant contributor in strengthening the performance of manufacturing organizations from their previous levels of performance (Randhawa and Ahuja, 2017). They also stated that the implementation of 5S has resulted in significant positive impacts, namely overall organizational achievement, production-related achievements, quality and continuous improvement achievements, cost optimization, employee-related achievements, effective use of workspace, and safety-related achievements in most manufacturing organizations. The following are the 5S principles, namely Seiri (sort, clean), Seiton (set in order/configure), Seiso (shine/clean and check), Seiketsu (Standardize/conformity), and Shitsuke (sustain/Custom and practice) (Randhawa and Ahuja, 2017).

2.4 *Eliminate, Combine, Rearrange, Simplify* (ECRS)

ECRS is a motion study technique used to analyze processes in a production line (Suhardi et al., 2019). ECRS is one method used to consider and provide optimal results (powerful) for any procedure that causes non-value-added working conditions identified with human work (Burawat, 2019). Practical application of the ECRS Principles improves labor efficiency, thereby reducing labor costs (Fritzie, 2011). ECRS is an essential practice tool to improve manufacturing efficiency to improve production lines by eliminating detailed inspections and analyzing production lines (Kasemset et al., 2014). The ECRS method (eliminate, combine, rearrange, simplify) is simple in its application and use; thus, this method is suitable for its improvement process. The ECRS concept can increase line efficiency by increasing production targets because the ECRS concept can eliminate, combine, rearrange, and simplify ineffective and inefficient work elements (Pertiwi and Astuti, 2020). According to him, the implementation of ECRS can reduce the total work content time, improve balance efficiency, reduce balance delays so that companies can achieve production targets due to a decrease in overall cycle time or maximum station time and an increase in production output.

2.5 *Teoriya Resheniya Izobreatatelskikh Zadatch* (TRIZ)

TRIZ is an acronym for the Russian word Teoriya Resheniya Izobreatatelskikh Zadatch or Theory of Inventive Problem Solving. TRIZ is a human-oriented, knowledge-based systematic methodology of creative problem solving (Savransky, 2000). TRIZ is a proven method for enhancing innovation, helping to face problems from a completely different and new perspective, bringing new ideas and visions (Rodríguez et al., 2016). Furthermore, TRIZ is an effective tool for repairing defects to increase company productivity (Rafsanjani and Singgih, 2018) and (Hakim &

Singgih, 2019). There are four (4) stages in the procedure for using TRIZ, according to (Rantanen and Domb, 2002), namely:

- Formulate the problem
- Find the contradiction attribute and create a matrix using TRIZ through 39 engineering parameters.
- Find solutions to existing problems by looking at 40 inventive principles
- Apply general TRIZ problem solving to more specific solutions.

3. Methodology

The data collection stage will take company data to obtain the information needed to complete this research. The data needed will be in the form of primary and secondary data. The following are the stages of DMAIC used in this study:

3.1 *Define*

Do a production process breakdown using flowcharts and classify and describe the physical flow and company information using Value Stream Mapping. Conduct interviews with production Managers, Quality Control Managers, and operators to identify critical waste in the production process.

3.2 *Measure*

This measurement stage will calculate the value of DPO, DPMO, Sigma Level, and Process Capability and compare with the target set by the company. The formula for determining the value of DPMO is as follows (Pande et al., 2000):

$$\text{Defect per opportunity (DPO)} = \frac{\text{Number of Defects}}{\text{Number of Units} \times \text{of Opportunities}}$$

$$\text{Defects per million opportunities (DPMO)} = \text{DPO} \times 1000000 \quad \ldots\ldots\ldots\ldots(3.1)$$

Based on the DPMO above, then determine the sigma level by calculating the following based on the following formula (Pyzdek, 2003):

$$\text{Level Sigma} = \text{Normsinv} = \left(\frac{1000000 - \text{DPMO}}{1000000}\right) + 1.5 \quad \ldots\ldots\ldots\ldots(3.2)$$

The Capability process (Cp) value is the ability of the current process to produce products that meet predetermined specifications. The following is a calculation to determine the value of the production process capability (Rafsanjani and Singgih, 2018):

$$\text{Capability Process (Cp)} = \frac{\text{Level Sigma}}{3}. \quad \ldots\ldots\ldots\ldots(3.2)$$

3.3 Analysis and Improvement

At this stage will use ECRS to determine which activities will be eliminated, combined, reworked, and simplified and TRIZ to make improvements according to the research objectives. Implementing TRIZ will begin with selecting the existing technical problems and defining the problems, determining the formulation of an ideal alternative solution, and making contradictions of the problems in each critical waste. In addition, it will find the contradiction matrix on waste, integrate it with 40 inventive principles, and determine the best solution based on the contradiction matrix, which has the best trade-off based on the contradiction parameter relationship.

4. Results and Discussion

4.1 Define

This study discusses defects in the Concrete Block production process at the CBBI company in February 2021. The current VSM shows that the cycle time is 106 minutes. Of the total cycle time, the time for value-added activities (4 activities) is only 38 minutes, or equivalent to 36% of the total cycle time. Meanwhile, the necessary non-value-added (18) and non-value added (4) activities are 51% and 13% of the total cycle time, respectively. The existence of necessary non-value-added activities and non-value-added activities indicates waste in the Concrete Block production process. In addition, the define stage also finds critical activities; the result is that defect waste is the most critical waste with a percentage of 25%.

4.2 Measure

The February 2021 process capability measurement and the DPMO (Defect per Million Opportunities) value can be inverted to determine the probability of a defective product. Table 1 shows the recap of Sigma and DPMO capabilities in the Concrete Block production process.

Table 1 Capability of Sigma and Dpmo in the Current Process

Process characteristics	Project	% defect	DPMO	Sigma Level
Sigma and DPMO capabilities on current processes	Concrete Block production process improvement	1.31 %	13128.7	3.7

Then convert the DPMO value into the sigma level. The sigma level is 3.7. However, in a Six Sigma project, this value is still categorized as low because the Six Sigma project aims to achieve process capability at the 6 Sigma control level to produce a probability of failure of 3.4 per million opportunities.

The calculation of process capability (Cp) in the current Concrete Block production process shows that it has not yet reached its target, which currently has a process potential index value of 1.23, and its target value is 1.5. Therefore, based on the Cp value, the production of Concrete Block products is good. However, the Cp value does not reach the target specification set by the company (Cp 1.5). Therefore, it still needs to be improved because the Cp value is below 1.5, so there must be an improvement stage to reduce the value of DPMO to increase the level of Sigma and the capability of the Concrete Block production process. The following in Table 2 is a comparison of existing and targets to be achieved by the company.

Table 2 Comparison of Existing and Target Cp and Sigma Levels

Process characteristics	% defect	Cp	Sigma Level
Current condition	1.31 %	1.23	3.7
The expected conditions	<1%	1.5	4.5

4.3 *Analyze*

The Concrete Block Production Manager carries out the determination of these two values. The following results from an assessment of each root cause of defects from the risk assessment matrix. Table 3 shows that all four root causes of defects were high and moderate root causes and find improvements to address the root cause.

Table 3 Defect Root Cause Impact Assessment

No	Root Cause	Likelihood value	consequences value	Risk value	Risk Rating
1	There is no means of transportation to replace employees	5	4	20	*High*
2	There is no formal quality standard	4	3	12	*Moderate*
3	Lack of awareness on health & safety	4	3	12	*Moderate*
4	The concrete block dough has not been mixed evenly	3	3	9	*Moderate*

4.4 *Improvement*

- ***Eliminate, Combine, Rearrange and Simplify* (ECRS) Method**

With the application of the ECRS method, the problem of mortar mixture is not suitable due to the absence of formal quality standards. Kneading again due to immature dough is recommended to eliminate these problems by creating or applying 5S principles and knowledge sharing. The re-aligning pallets that are not following the need to remove them by installing pallets need to reduce rework. Separating defective Concrete Blocks and re-destroying also needs to be eliminated by implementing 5S and knowledge sharing. In addition, the problem of lack of awareness of health and safety (work culture) needs to be improved and simplified again with the idea, namely Cultivating workers with 5S.

- ***Teoriya Resheniya Izobreatatelskikh Zadatch* (TRIZ) Method**

We will use the TRIZ method to find suitable alternative solutions in repairing the problems that cause defects in the CBBI company based on the analysis results (5-whys) and recommendations from the ECRS method for rearranging simplifying. This process identifies existing matrix contradictions related to the parameters involved in each rearranges, simplifies solutions, and determines the TRIZ innovation principle for each technical response. Therefore, the TRIZ method has 39 engineering parameters and 40 Inventive Principles (Innovative), where 39 engineering parameters vital factors to make comparisons (contradiction), and 40 Inventive Principles (Innovative) will emerge as innovative solutions from TRIZ.

Contradiction

In the production process of Concrete Block, there are contradictory problems that make it difficult to minimize waste. Therefore, matrix contradictions need to be analysed to reduce the company's defective products in Concrete Block. In the production process of Concrete Block, some contradictions and problems become obstacles to the process so as not to produce a product that is not defective. Therefore, this matrix contradiction is an obstacle in the production process of Concrete blocks in achieving high quality. There are three general problems: work standards, mortar dough, and transportation equipment (Material Handling).

Contradiction to Standards of work

- Failure/error minimization vs. Knowledge sharing/SOP socialization
  Loss of time (25) vs. Loss of energy (22)
- Vulnerability of producing defective products vs. detection of causes of waste
  External harm affects the objects (30) vs. Difficult of detecting and measuring (37)
- Does not cause deformed Concrete Block vs. minimization of impact or friction
  Object generated harmful factor (31) vs. stress or pressure object (11)

Recommendations for improvement are principle 10 (Preliminary Action), Do it before it is needed, changes are needed to an object or system, namely conducting training on SOPs and 5S to employees before giving assignments in the field. So, it is recommended to apply the 5S method in the workplace, conduct training, and regularly evaluate the implementation of SOPs in the field. Principle 19 (Periodic Action) does not take continuous action but uses periodic actions, namely cleaning the production floor as needed to keep the production floor clean and comfortable. In this case, the recommendation is to apply the 5S principle in the company. The advantage of checking and cleaning the production area is ensuring that all activities follow 5S standards to minimize problems (waste) caused by human error. Principle 2 (separation) separates the only necessary part (or property) or removes an object or system's interfering part or property. Eliminate all human errors and unorganized workplaces and a new work system that is more effective and efficient immediately designed. Mistakes include employees working carelessly, no evaluation of productivity, and applying 5S, and continuous knowledge sharing.

Contradictions in Mortar Dough

- Appropriate raw material sizing vs. minimization of rework
  Measurement accuracy (28) vs. Loss of time (25)
- Appropriate raw material sizing vs. minimization of rework
  Measurement accuracy (28) vs. durability of a non-moving object (16)

The improvement recommendation given is principle 24 (Intermediary) using an intermediary object or intermediary process. Recommend that the company add additional tools in the form of CCTV installation in the mixer to monitor the mortar or mortar mixture results so that re-mixing does not occur again after the product looks defective. The position of the CCTV is placed towards the results of the mortar dough to determine whether the mixture is good enough or not before transferring the mortar to the Concrete Block moulding machine, and CCTV can also help the activities and conditions of the machine and its surroundings. In addition, the CCTV can perform early detection of errors in the mortar mixing process. Principle 10 (Preliminary Action), do it before it is needed; changes are needed to an object or system, namely making adjustments to the correct standard of mortar dosage before transferring the mortar dough to the Concrete Block moulding stage. Suggest production managers adapt to the quality standards of Concrete Block implemented by the government. The advantage of carrying out Preliminary Action activities is that it can increase production productivity by minimizing defect waste.

Contradictions in Material Handling

- The conveyance is still manual vs. the speed of moving Concrete Blocks
  Level of automation (38) vs. speed (9)
- Optimal carrying capacity vs. Light equipment
  Volume stationery (8) vs. Weight of non-moving object (2)
- Strong conveyance vs. Light conveyance
  Strength (14) vs. Weight of non-moving object (2)
- Simple vs. Easy to use
  Shape (12) vs. Convenience of use (33)

The recommendations for improvement given are Principle 10 (Preliminary Action), do, before needed, changes to the required object (either entirely or partially), namely making changes to the transportation equipment (material handling) used, for example, replacing carts with other material handling equipment that can minimize the lifting of Concrete Blocks by employees. Principle 35, parameter changes, reads "Change the degree of flexibility." This principle gives the idea of needing a Concrete Block conveyance that is flexible, easy to use, and easy to repair. Finally, principle 26 uses other material handling or copies that are cheap and easy to obtain.

- **5S method**

Based on the analysis, measurement, and recommendation by the ECRS and TRIZ methods for implementing the 5S principle, the 5S method will be applied to help perfect the previous improvement solutions to waste problems in CBBI. First, the series (sort) is sorting between the types of equipment (shovels, pallets, water hoses, socket wrenches) that are necessary, unnecessary, and empty. Then, remove unnecessary and empty equipment from the workplace. Second, implement Seiton (set in order) by keeping pallets suitable for frequent and essential use. Written and hung posters or labels are provided to reduce errors and are easy to use for reminding. Third, Seiso (shine) maintains cleanliness regularly so that there are no remnants that cause problems with speed and safety on the path of moving Concrete Blocks and the scenery at work. Furthermore, Seiketsu (standardization) sets the standard time and amount of storage, scheduling, and storage based on the standard quantity and time. Finally, Shitsuke (sustain) is implemented by maintaining the improved system above, communicating and announcing to all employees that 5S is essential and requires collaboration from workers and cohesive self-discipline regarding the application and adherence to regular rules in SOP implementation cleaning, and sorting.

5. Conclusion

The conclusions from this research are as follows:

1) The VSM shows that the cycle time is 106 minutes. Of the total cycle time, the time for value-added activities is only 38 minutes, or equivalent to 36% of the total cycle time. Meanwhile, the necessary non-value added and non-value-added activities are 51% and 13% of the total cycle time, respectively.
2) The rank of waste based on the largest to the most negligible Weight, namely: Waste of Defects with a weight value of 25%, Waste of Motion with a weight value of 18% Waste of Transportation with a weight value of 17%, Waste of Waiting with a weight value of 15%, Waste of Overprocessing with a weight value of 9%, Waste of Overproduction with a weight value of 8% and Waste of Inventory 7%.
3) In calculating the DPMO value of 13128.75 with a sigma level of 3.7 and the process capability of 1.23, this value still needs to be increased to achieve the company's target.

4) Root Cause Analysis results show several causes of the waste defect: no means of transportation to replace employees, no formal quality standard, lack of awareness of health & safety, and the mortar mix is not yet ripe.
5) Based on the root of the problem, the company needs to carry out several improvement processes:
   - It is necessary to apply the 5S method in the workplace and conduct training and evaluate the implementation of the operational standard in the field regularly to minimize human errors and increase the work motivation of workers.
   - Carry out cleaning the production floor as needed to keep the production floor clean and comfortable and install CCTV in the mixer to monitor mortar or mortar dough results so that re-mixing does not occur again after the product looks defective. In addition, making adjustments to the quality standards of Concrete Block is applied by the government to meet the quality and expectations of users.
   - Requires transportation equipment (material handling) of Concrete Block that is flexible, easy to use, and easy to repair to help ease employees' work and use other material handling materials that are cheap and easy to obtain to minimize waste.

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