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Integrated Seven Tools Approach Reduces Flat Glass Defects: Integrasi Pendekatan Seven Tools Untuk Mengurangi Cacat Kaca Lembaran

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Abstract

General Background: Product quality control is a central requirement in manufacturing because defects can reduce production performance, increase waste, and weaken company reputation. **Specific Background:** PT XYZ, a major flat glass manufacturer in Indonesia, faced quality problems in flat glass production during January to September 2025, including inclusion, shellchip, scratch, and stain. **Knowledge Gap:** The manuscript identifies the need for structured defect analysis, causal diagnosis, and priority repair strategies to minimize flat glass product defects. **Aims:** This study aimed to identify flat glass defect types using Seven Tools and formulate quality improvement proposals using New Seven Tools. **Results:** The study recorded 567 defective units. Shellchip was the dominant defect, accounting for 50% or 285 units, followed by scratch at 22% or 123 units, inclusion at 16% or 91 units, and stain at 12% or 68 units. The proposed priority improvements were tightening raw material quality checks from suppliers, implementing double checks during press cutter machine setting, routinely cleaning dirt on the roll, conducting spray tests before coating, and creating a preventive maintenance schedule for coating machines. **Novelty:** The study combines Seven Tools for quantitative defect analysis with New Seven Tools for structured causal exploration and improvement prioritization. **Implications:** The findings offer practical quality control actions for reducing flat glass defects and strengthening production reliability.

Highlights:

- A total of 567 faulty units were recorded from January to September 2025.
- Scratch, inclusion, and stain followed at 22%, 16%, and 12%.
- Five priority actions addressed supplier checks, cutter setup, roll cleaning, spraying, and maintenance.

Keywords: Flat Glass, New Seven Tools, Product Defect, Seven Tools, Quality Control

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Introduction

The manufacturing industry is a leading sector in the national economy through its contribution to Gross Domestic Product (GDP) [1]. This makes competition in the manufacturing industry increasingly fierce, making product quality one of the main factors determining the success of a company's competitiveness [2]. Quality control is a key aspect in the production process to obtain production results that meet consumer standards and expectations [3]. Quality control is carried out with the aim of minimizing production errors, reducing the number of defects and production errors, completing products on schedule, and minimizing operational costs [4].

PT XYZ is one of the largest glass manufacturers globally with one of its factories located in Sidoarjo as a supplier of flat glass in Indonesia. As one of the flat glass manufacturers in Indonesia, the company faces challenges related to the quality of its flat glass products in the form of product defects that appear during the production process. The percentage of defects in flat glass products is 6,6% or 567 units out of a total production sample of 8569 units during the period January - September 2025. The types of defects in flat glass products include inclusion, shellchip, scratch, and stain. Product defects that appear in the resulting flat glass can cause waste and reduce the company's reputation. Therefore, an analysis of defects and the factors causing defects in flat glass products is needed, as well as an effective repair strategy to minimize the occurrence of product defects. Production data and defect data can be seen in table 1.

Table 1. Production Data and Number of Defects in Flat Glass Products

Month	Product Sample (unit)	Number of Defects (unit)	Defect Percentage
Januari	1333	88	6,6%
February	970	60	6,2%
March	512	31	6,1%
April	479	31	6,5%
May	1415	96	6,8%
June	1160	78	6,7%
July	1230	82	6,7%
August	1044	71	6,8%
September	426	30	7,0%
Total	8569	567	59,3%
Average Percentage of Defects			6,6%

Quality control is the primary step in addressing the problems in this study. Problems related to defects in flat glass products at PT XYZ were analyzed by analyzing the factors causing defects in flat glass products based on the level of defects that occurred. The analysis was carried out using the Seven Tools and New Seven Tools methods. Seven Tools are statistical quality control tools to address problems that arise during the production process [5]. Meanwhile, New Seven Tools is a tool for qualitative exploration by conceptualizing and planning that focuses on a structural approach to problem solving [6]. The two methods were used together in the study, where Seven Tools was used as a tool for analyzing defects in flat glass products, while New Seven Tools was used as a tool for analyzing the causes of defects and proposing improvements that can be implemented by the company to improve product quality.

Based on the explanation above, the Seven Tools and New Seven Tools methods were selected as appropriate for this research. This is because both methods can produce results consistent with the research objectives. The purpose of this research is not only to analyze product defects but also to propose improvements to improve the quality of flat glass products.

Method

In the initial stages of the research, primary and secondary data were collected for analysis of product defects. Primary data in the research was obtained through direct observation of the flat glass production process and interviews with several parties directly involved in the production process and quality control. Meanwhile, secondary data was obtained from the company's historical data in the form of production volume data, product defect data, defect type data, and questionnaire data.

Data analysis was then conducted using the Seven Tools and New Seven Tools methods. There are seven analytical tools in the Seven Tools method, namely Check Sheets, Stratification, Histogram, Pareto Chart, Scatter Diagram, Control Chart, and Fishbone Diagram. Meanwhile, in the New Seven Tools method, the analytical tools used are Activity Network Diagram, Affinity Diagram, Interrelationship Diagram, Tree Diagram, Matrix Diagram, Matrix Data Analysis, and Process Decision Program Chart (PDPC). The research flow can be seen in Figure 1.

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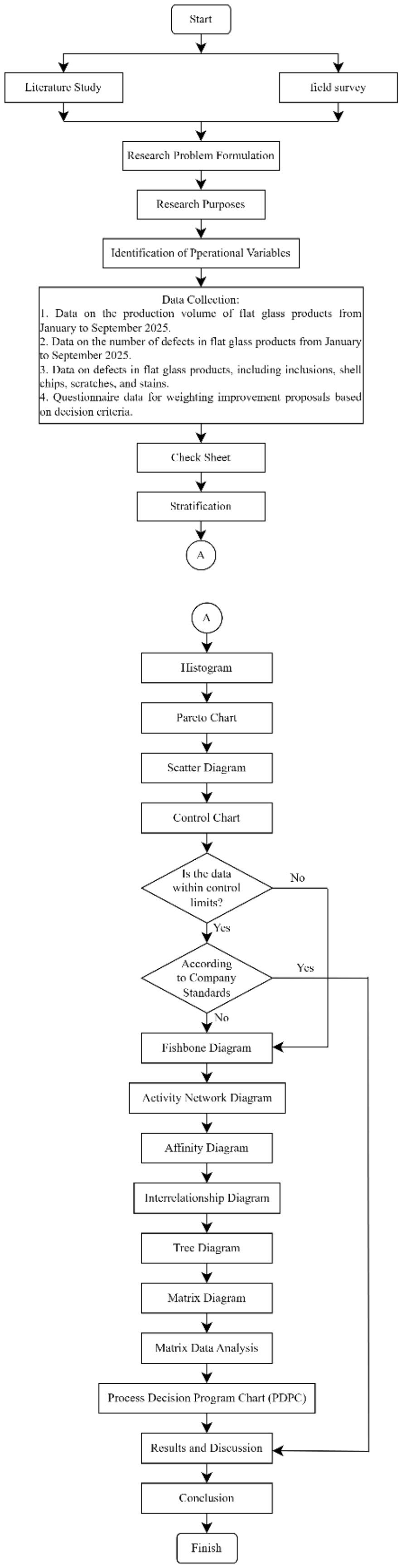

Figure 1. Flowchart

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Result and Discussion

A. Seven Tools

Data processing using the Seven Tools method is carried out with seven quality control tools, including Check Sheet, Stratification, Histogram, Pareto Chart, Scatter Diagram, Control Chart, and Fishbone Diagram.

1. Check Sheet

A check sheet is a data collection sheet used to record necessary research data [7]. The collected defect data for flat glass products can be seen in the Table 2.

Table 2. Check Sheet

Flat Glass										
Observer Name: Citra Wahyuning Gati										
Observation Location: PT XYZ										
Observation Date: January - September 2025										
Defect	Months									**Total**
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	
Inclusion	EEEA A	EAAA A	AAA	EA	EEAAA	EEAAA A	EAAA	EEEAA	AAAA	**91**
Shellchip	EEEE E EEEE E AA	EEEE EAAA	EEEEAA A	EEAAA A	EEEEE EEEEAAA A	EEEEE	EEEE E EEEE A	EEEEE AAAA	EEAAA A	**285**
Scratch	EEA	EEAA A	AAA	EAA	EEEEAAA	EEEEE EAAAA	EEAA A	EEA	EAAA	**123**
Stain	EAAA	E	AA	AAAA	EEA	E	EEE	EEAAA A	AAAA	**68**
Total	**88**	**60**	**31**	**31**	**96**	**78**	**82**	**71**	**30**	**567**

The recapitulation of total defects in flat glass products during the period January - September 2025 is 567 units. Shellchip defects that occurred were 285 units, followed by scratch defects of 123 units, inclusion defects of 91 units, and stain defects of 68 units. When viewed each month, the highest defects occurred in May with 96 units and the lowest defects occurred in September with 30 units. Inclusion defects most frequently occurred in January and August with 17 units, shellchip defects most frequently occurred in January with 51 units, scratch defects most frequently occurred in June with 34 units, and stain defects most frequently occurred in July with 15 units.

2. Stratification

Stratification is a table used to group data based on defect categories [8]. The results of grouping data based on the Check Sheet can be seen in the Table 3.

Table 3. Stratification

No	**Defect**	**Numbers of Defects (unit)**	**Percentage of Defects (%)**	**Cumulative Percentage (%)**
1	*Inclusion*	91	16	16
2	*Shellchip*	285	50	66
3	*Scratch*	123	22	88
4	*Stain*	68	12	100
Total		**567**	**100**	

Shellchip defects have a defect percentage of 50%, which is 285 units of the total defects, scratch defects have a defect percentage of 22%, which is 123 units of the total defects, inclusion defects have a defect percentage of 16%, which is 91 units of the total defects, and stain defects have a defect percentage of 12%, which is 68 units of the total defects.

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3. Histogram

Histogram is a bar chart that shows the level of variation in data in the form of a pattern of defect data based on the number of defects [9]. The level of variation in defect data can be seen in the Figure 2.

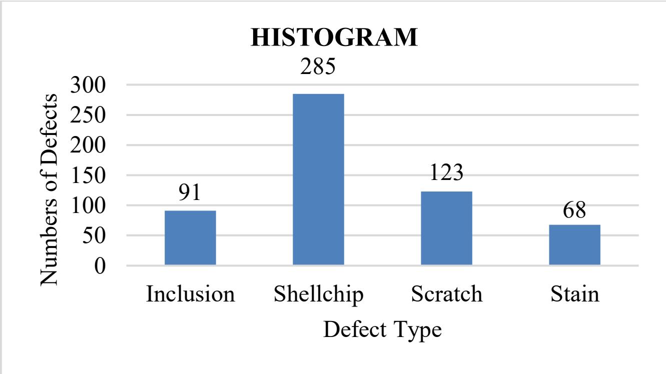

Figure 2. Histogram

Shellchip defects are the most dominant defect, namely 285 units. The second dominant defect is scratch defects with 123 units, followed by inclusion defects with 91 units and stain defects with the smallest occurrence, namely 68 units.

4. Pareto Chart

Pareto diagram is a comparison diagram of each type of data against the overall data, depicted in both bar and line graphs. The calculation of the percentage of defects and the cumulative percentage of defects for each type is based on the results of the Stratification calculation [10]. The Pareto diagram used in this study can be seen in the Table 3.

Table 3. Percentage of Defects

No	Defect	Numbers of Defects (unit)	Percentage of Defects (%)	Cumulative Percentage (%)
1	*Shellchip*	285	16	16
2	*Scratch*	123	50	66
3	*Inclusion*	91	22	88
4	*Stain*	68	12	100
Total		**567**	**100**	

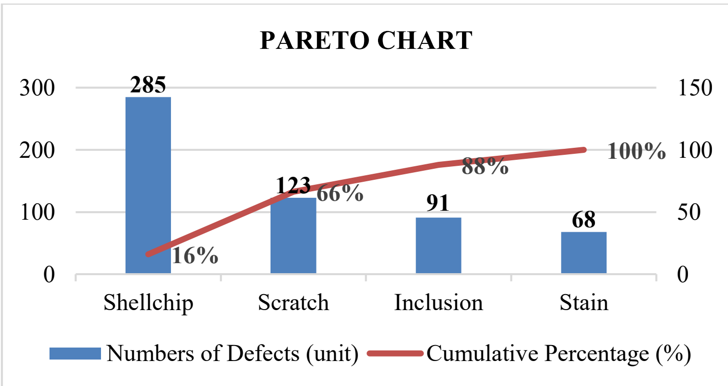

Figure 3. Pareto Chart

Shellchip defects are the most dominant type of defect that occurs with a percentage of 50%. The second dominant defect is scratch defects with a percentage of 22%, followed by inclusion defects with a percentage of 16% and stain defects being the smallest type of defect that occurs with a percentage of 12%.

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5. Scatter Diagram

Scatter Diagram is a diagram that shows the correlation or relationship between a cause or factor and a product's quality characteristics [10]. The scatter diagram in this study can be seen in the Figure 4.

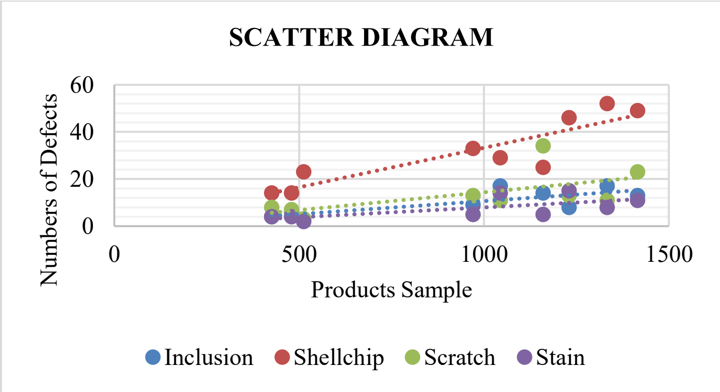

Figure 4. Scatter Diagram

There is a positive relationship or correlation between the products sample and the number of defects for each type of defect. This means that the higher the products sample, the higher the number of defects produced.

6. Control Chart

Control Chart is a graph that displays a pair of upper and lower limit lines with a control line inside [11]. Control Charts are created for each type of defect to determine the defect conditions for each type of defect. The Control Chart used in this study can be seen in the Figure 5 until Figure 8.

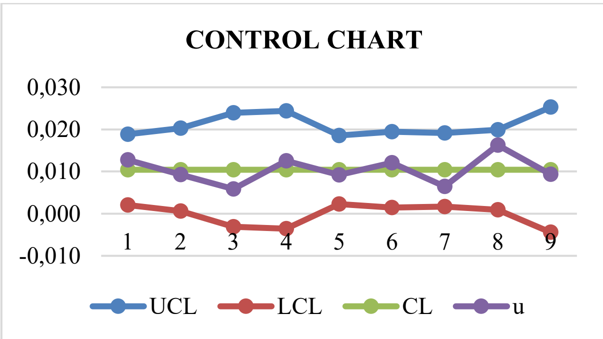

Figure 5. Control Chart of Inclusion Defect

Inclusion defects there is no defect data that is outside the upper control limit (UCL) or lower control limit (LCL) so it can be said that the production process is still under control. The average inclusion defect is 16% and is not in accordance with the company standard of 5% so it is necessary to conduct further analysis regarding the causes of inclusion defects and proposed improvements that can be implemented to minimize the occurrence of inclusion defects.

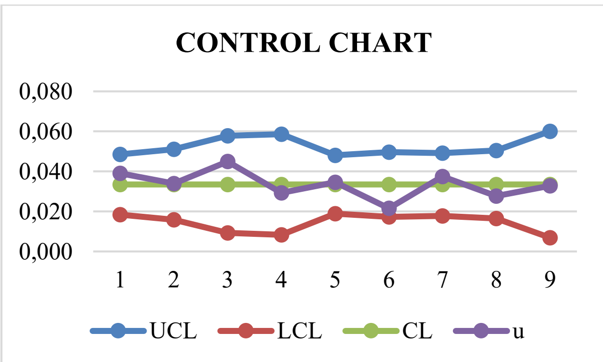

Figure 6. Control Chart of Shellchip Defect

Shellchip defects there is no defect data that is outside the upper control limit (UCL) or lower control limit (LCL) so it can be said that the production process is still under control. The average shellchip defect is 50% and is not in accordance with the company standard of 5% so it is necessary to conduct further analysis regarding the causes of shellchip defects and proposed improvements that can be implemented to minimize the occurrence of shellchip defects.

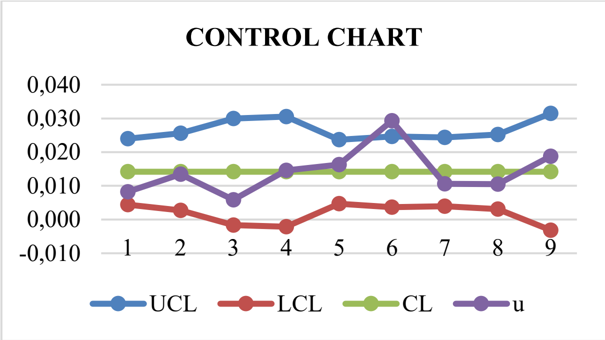

Figure 7. Control Chart of Scratch Defect

Scratch defects there are still defect data that are outside the upper control limit (UCL) namely in the period of June 2025 and there are no defect data that are outside the lower control limit (LCL). This shows that the production process is still not under control, especially in June 2025, so it is necessary to analyze the causes of scratch defects and propose improvements that can be implemented to minimize the occurrence of scratch defects.

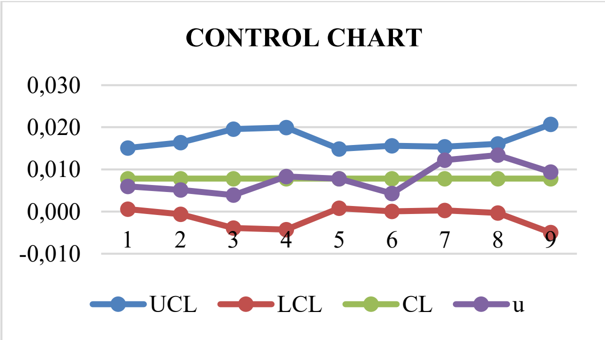

Figure 8. Control Chart of Stain Defect

Stain defects there is no defect data that is outside the upper control limit (UCL) or lower control limit (LCL) so it can be said that the production process is still under control. The average stain defect is 12% and is not in accordance with the company standard of 5% so it is necessary to conduct further analysis regarding the causes of stain defects and proposed improvements that can be implemented to minimize the occurrence of stain defects.

7. Fishbone Diagram

Fishbone Diagram resembles a fishbone and is used to identify the causes of defects or problems [12]. Fishbone Diagram is identify the causes of defects in each type of defect, namely inclusion defects, shellchip defects, scratch defects, and stain defects. The Fishbone Diagram used in this study can be seen in the Figure 9 until Figure 12.

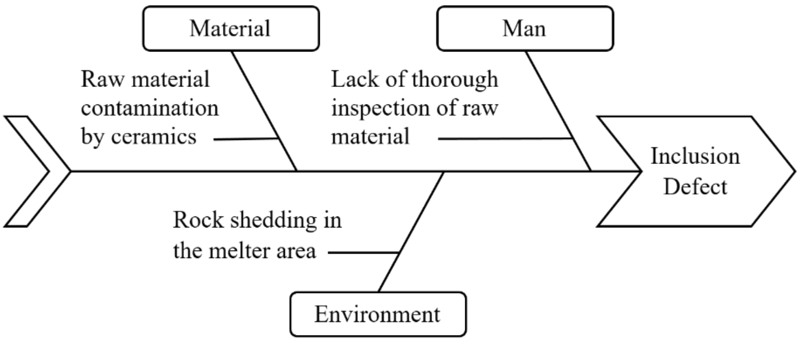

Figure 9. Fishbone Diagram of Inclusion Defect

Inclusion defects are caused by several factors, namely human, material, and environmental factors. In terms of human factors, defects occur due to a lack of thorough inspection of raw materials before the production process. In terms of material factors, defects occur due to raw material contamination by ceramics. In terms of environmental factors, defects occur due to rock shedding in the melter area.

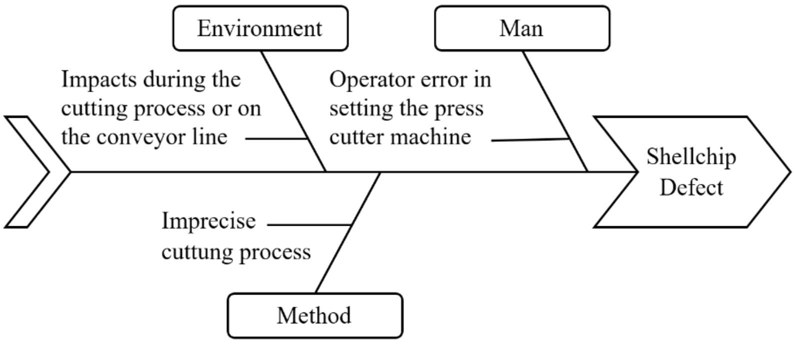

Figure 10. Fishbone Diagram of Shellchip Defect

Shellchip defects are caused by several factors: human, method, and environmental. In terms of human factors, defects occur due to operator error in setting the press cutter machine. In terms of method factors, defects occur due to imprecise cutting processes. Meanwhile, in terms of environmental factors, defects occur due to impacts during the cutting process or on the glass conveyor line.

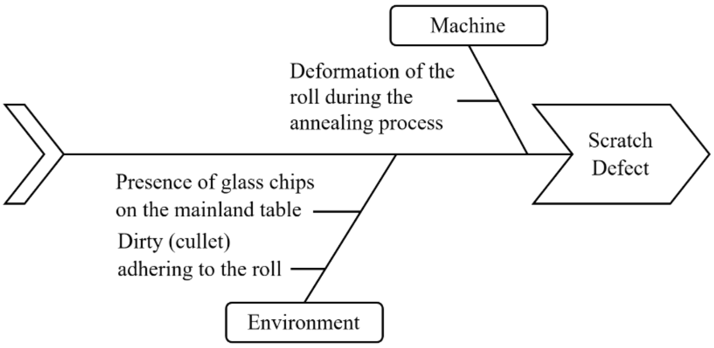

Figure 11. Fishbone Diagram of Scratch Defect

Scratch defects are caused by several factors, namely the machine and the environment. In terms of the machine, the defect occurs due to deformation of the roll during the annealing process. In terms of the environment, the defect occurs due to the presence of glass chips on the mainland table and dirt (cullet) adhering to the roll.

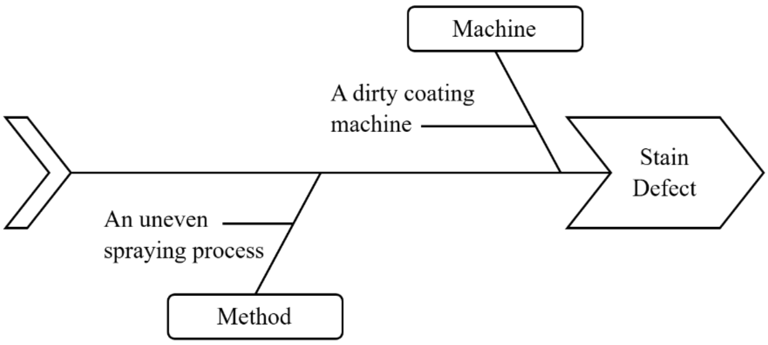

Figure 12. Fishbone Diagram of Stain Defect

Stain defects are caused by several factors, namely the machine and the method. In terms of the machine factor, defects occur due to a dirty coating machine. In terms of the method factor, defects occur due to an uneven spraying process.

B. New Seven Tools

Data processing using the New Seven Tools method is carried out with seven quality control tools, including Activity Network Diagram, Affinity Diagram, Interrelationship Diagram, Tree Diagram, Matrix Diagram, Matrix Data Analysis, and Process Decision Program Chart (PDPC).

1. Activity Network Diagram

Activity Network Diagram displays the production process flow, duration, and dependencies of activities within a process [13]. The Table 4 shows the production activities for a flat glass product.

Table 4. List of Activities and Duration of the Flat Glass Production Process

List of Activities	Activity Code	Previous Activity	Process Duration
Receipt of raw materials from suppliers (receiving process).	A	-	70 minutes
Mixing raw materials in the batch house area (preparation process).	B	A	45 minutes
Melting the raw material mixture at a temperature of 1650°C (melting process).	C	B	720 minutes
Removing bubbles at a temperature of 1200°C (refining process).	D	C	240 minutes
Flowing hot glass into molten tin (drawing process).	E	D	40 minutes
Slowly cooling the glass (annealing process).	F	E	50 minutes
Washing glass with water (washing process	G	F	15 minutes
Online glass inspection process using a defect detector (booth room).	H	G	2 minutes
Glass coating process with chemical spray.	I	H	4 minutes
Cutting glass to size (cutting process).	J	I	10 minutes
Checking production results by quality control.	K	J	25 minutes
The product storage process in the production warehouse.	L	K	20 minutes

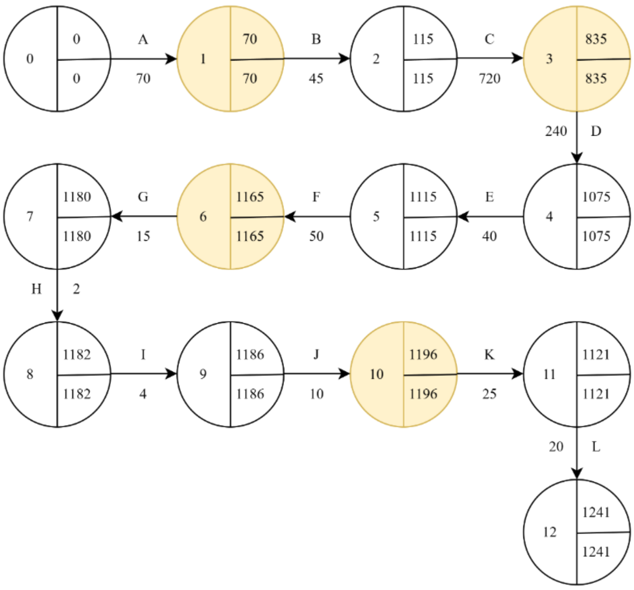

Figure 13. Activity Network Diagram

There are 12 process stages in the sheet glass production process starting from the initial receipt of raw materials to storage in the product warehouse which requires a process time duration of 1241 minutes.

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2. Affinity Diagram

Affinity Diagram is a diagram used to organize defect problems into groups based on similarities between items [13]. The Affinity Diagram for type of defect in flat glass products can be seen in Figure 14.

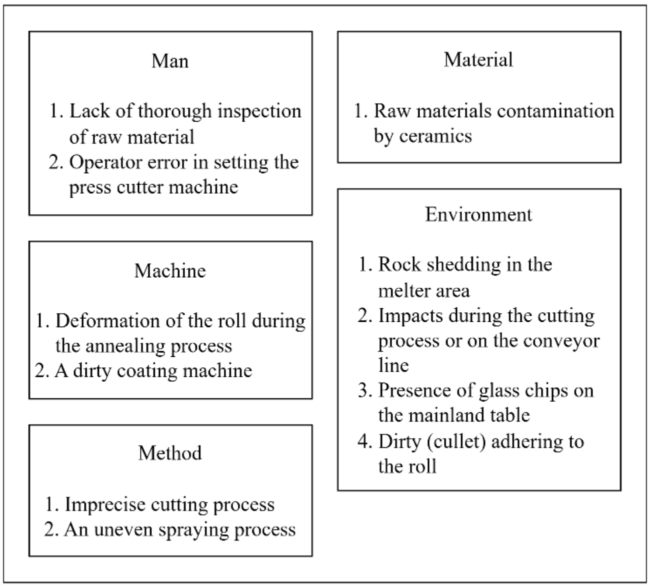

Figure 14. Affinity Diagram

Defects occur due to several factors, namely humans, materials, machines, methods and the environment. In terms of human factors, defects occur due to a lack of thorough inspection of raw materials before the production process and operator error in setting the press cutter machine. In terms of material factors, defects occur due to raw material contamination by ceramics. In terms of machine factors, defects occur due to deformation of the roll during the annealing process and a dirty machine coating. In terms of environment factors, defects occur due to rock shedding in the melter area, impacts during the cutting process or on the glass conveyor line, the presence of glass chips on the mainland table, and dirt (cullet) adhering to the roll. In terms of method factors, defects occur due to imprecise cutting process and an uneven spraying process.

3. Interrelationship Diagram

Interrelationship Diagram is a diagram to identify relationships between problems by showing factors that are interrelated and influence each other [14]. The Interrelationship Diagram in the research can be seen in the Figure 15.

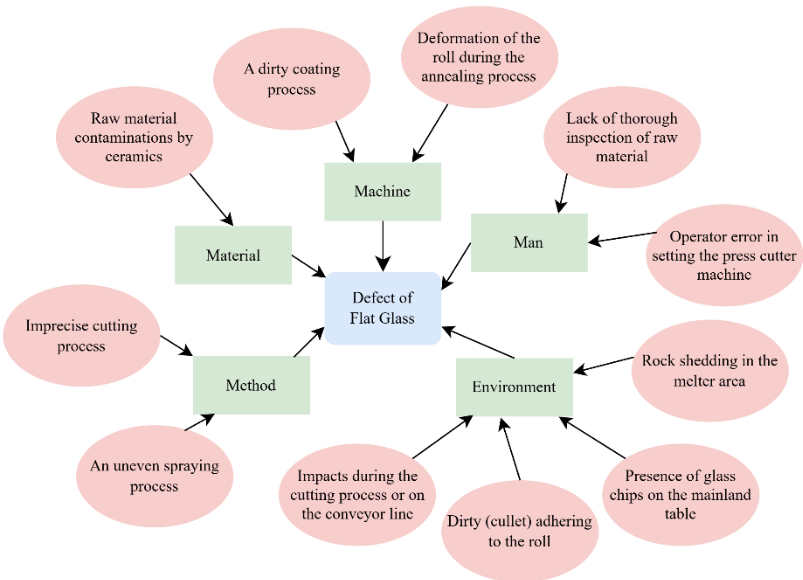

Figure 15. Interrelationship Diagram

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Interrelationship Diagram shows that interconnected relationship can have influence on each other that makes defect on flat glass product.

4. Tree Diagram

Tree Diagram is a diagram used to break down a problem into smaller components and subcomponents, helping to demonstrate the relationships between them [14]. The problem-based solutions or improvement alternatives for reducing defects in flat glass products are shown in the Figure 16.

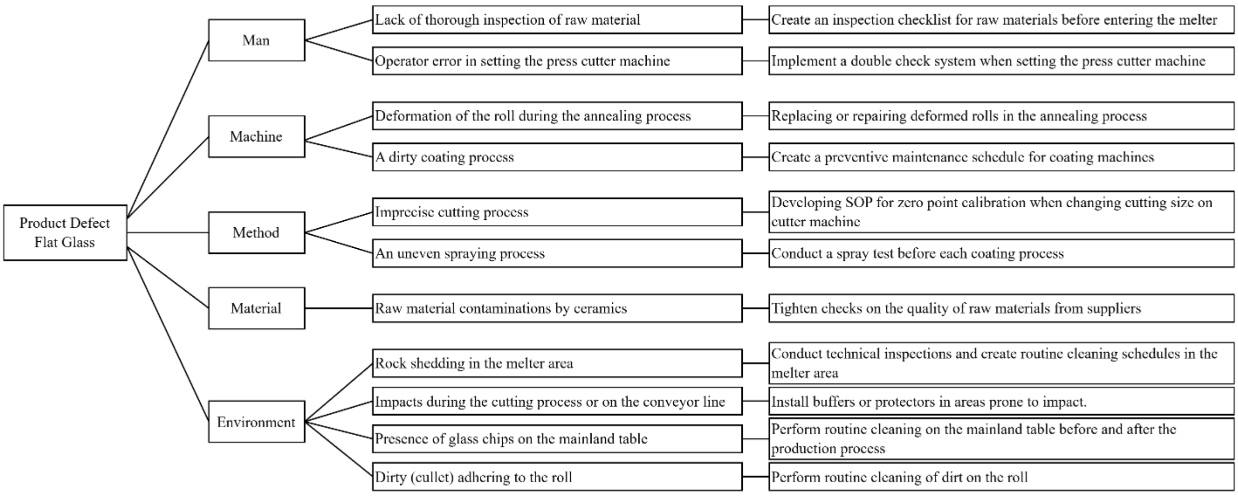

Figure 16. Tree Diagram

5. Matrix Diagram

Matrix Diagram is a diagram that shows the relationship between problems, solutions, and corrective actions to help analyze the interrelationships so that priority can be determined for improvement [15]. In this study, the type of matrix used is the L-Matrix Diagram which has been adjusted based on the data that has been collected regarding the causes of defects in sheet glass products. Improvements made include improvements in terms of humans, materials, machines, methods, and the environment. The strength of each relationship is denoted by three symbols, namely a full circle which means a strong relationship and has 9 points, an empty circle which means a medium relationship and has 3 points, and a red triangle which means a weak relationship and has 1 point. The calculation of the closeness value between the defect factor and the cause of the defect is done by adding up all the scores for each factor.

Table 5. Matrix Diagram of the Relationship Between Defect Factors and Causes of Defect

Cause of Defect	**Symbol of the Relationship Between Defect Factors and Causes of Defect**					**Score**
	Man	**Machine**	**Method**	**Material**	**Environment**	
Lack of thorough inspection of raw material.	●	▲	○	○	▲	17
Operator error in setting the press cutter machine.	●	○	○	▲	▲	17
Deformation of the roll during the annealing process.	▲	●	▲	▲	○	15
A dirty coating process.	○	●	○	▲	○	19
Imprecise cutting process.	○	○	●	▲	▲	17
An uneven spraying process.	▲	○	●	▲	▲	15
Raw material contaminations by ceramics.	○	▲	○	●	○	19
Rock shedding in the melter area.	▲	○	▲	○	●	17
Impacts during the cutting process or on the conveyor line.	○	○	▲	▲	●	17

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Cause of Defect	Symbol of the Relationship Between Defect Factors and Causes of Defect					Score
	Man	Machine	Method	Material	Environment	
Presence of glass chips on the mainland table.	▲	○	▲	○	●	17
Dirty (cullet) adhering to the roll.	○	○	○	▲	●	19

The causes of defects that have an impact on the quality of sheet glass products include operator error in setting the press cutter machine, dirty coating machines, imprecise cutting processes, raw materials contaminated with ceramics, and the presence of dirt (cullet) attached to the roll. These five causes of defects were selected based on the value of the greatest closeness of the relationship between the cause of the defect and the defect factor.

Table 6. Matrix Diagram of the Relationship between Defect Factors and Proposed Improvements

Proposed Improvements	Symbol of the Relationship Between Defect Factors and Proposed Improvements					Score
	Man	Machine	Method	Material	Environment	
Create an inspection checklist for raw materials before entering the melter.	●	▲	○	○	▲	17
Implement a double check system when setting the press cutter machine.	●	○	○	▲	▲	17
Replacing or repairing deformed rolls in the annealing process.	▲	●	○	▲	○	17
Create a preventive maintenance schedule for coating machines.	○	●	○	▲	▲	17
Developing SOP for zero point calibration when changing cutting size on cutter machine.	○	○	●	▲	▲	17
Conduct a spray test before each coating process.	○	○	●	▲	○	19
Tighten checks on the quality of raw materials from suppliers.	○	▲	○	●	▲	17
Conduct technical inspections and create routine cleaning schedules in the melter area.	○	○	○	▲	●	19
Install buffers or protectors in areas prone to impact.	▲	○	▲	▲	●	15
Perform routine cleaning on the mainland table before and after the production process.	○	▲	○	▲	●	17
Perform routine cleaning of dirt on the roll.	○	○	○	▲	●	19

The priority improvement proposals that can be implemented are implementing a double-check system when setting up the press cutter machine, creating a preventive maintenance schedule for the coating machine, conducting spray tests before each coating process, tightening checks on the quality of raw materials from suppliers, and conducting routine cleaning of dirt on the roll. These five improvement proposals were selected based on the value of the greatest closeness of the relationship between the improvement proposal and the defect factor.

6. Matrix Data Analysis

Matrix Data Analysis is used to analyze the importance of corrective actions and the problems that occur based on the collected data. The process requires respondent participation to assess proposed improvements to determine the top priority for correcting defects in flat glass products [15].

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Table 7. Decision Criteria

Proposed Improvement Code	Improvement Code	Criteria Code	Decision Criteria
1	Implement a double check system when setting the press cutter machine.	A	Improve cutting accuracy by implementing double checks to minimize setting errors by operators.
2	Create a preventive maintenance schedule for coating machines.	B	Maintain coating machine performance with preventive maintenance according to the schedule.
3	Conduct a spray test before each coating process.	C	Conduct initial spraying tests to ensure uniformity of spray results in the coating process.
4	Tighten checks on the quality of raw materials from suppliers.	D	Conduct strict inspections of raw material quality to minimize contamination, especially ceramics.
5	Perform routine cleaning of dirt on the roll.	E	Maintain the cleanliness of the roll regularly to prevent cullet from sticking to the roll.

Next, an important rating is calculated based on the respondents' assessments. The important rating values can be seen in the Table 8.

Table 8. Important Rating

Rating Code	R1	R2	R3	R4	R5	Score	Ranking
A	5	5	4	5	4	23	2
B	4	3	5	4	5	21	4
C	5	5	5	4	5	24	1
D	4	5	4	5	4	22	3
E	4	4	4	4	4	20	5

Then a ranking is determined based on the respondents' assessment for each criterion based on the proposed improvements.

Table 9. Final Ranking of Respondents' Assessments for Criterion A

Proposed Improvement Code	R1	R2	R3	R4	R5	Score	Ranking
1	5	5	4	5	4	23	1
2	2	2	3	2	1	10	5
3	2	2	3	2	2	11	2
4	2	2	2	3	2	11	3
5	2	2	3	2	2	11	4

Table 10. Final Ranking of Respondents' Assessments for Criterion B

Proposed Improvement Code	R1	R2	R3	R4	R5	Score	Ranking
1	2	2	3	2	2	11	4
2	5	5	4	5	4	23	1
3	4	4	4	5	4	21	2
4	2	2	3	2	2	11	5
5	3	3	3	4	3	16	3

Table 11. Final Ranking of Respondents' Assessments for Criterion C

Proposed Improvement Code	R1	R2	R3	R4	R5	Score	Ranking
1	3	4	3	3	3	16	3
2	4	4	4	5	4	21	2
3	5	5	4	5	5	24	1
4	2	3	2	2	2	11	5
5	3	3	3	4	3	16	4

Table 12. Final Ranking of Respondents' Assessments for Criterion D

Proposed Improvement Code	R1	R2	R3	R4	R5	Score	Ranking
1	2	2	2	3	2	11	4
2	3	3	3	4	3	16	2
3	2	2	3	2	3	12	3
4	5	5	4	5	5	24	1
5	2	2	2	2	3	11	5

Table 13. Final Ranking of Respondents' Assessments for Criterion E

Proposed Improvement Code	R1	R2	R3	R4	R5	Score	Ranking
1	2	2	2	2	3	11	4
2	3	4	3	3	4	17	2
3	3	3	3	4	3	16	3
4	2	2	2	2	3	11	5
5	5	5	4	5	5	24	1

After determining the ranking for each criterion based on the proposed improvements, a combining ranking table is created to group the ranking results. The combining ranking table contains a column for improvement criteria, which contains the ranking results in Table 8 (important ranking) and a table for improvement code, which contains the ranking results for each improvement proposal. The combining ranking table can be seen in the Table 14.

Table 14. Combining Ranking

Decision Criteria	Proposed Improvement Code				
	1	2	3	4	5
2	1	4	3	4	4
4	5	1	2	2	2
1	2	2	1	3	3
3	3	5	5	1	5
5	4	3	4	5	1

Next, a score is calculated for the proposed improvements based on the combining ranking table. The scores for the proposed improvements can be seen in the Table 15.

Table 15. Proposed Improvement Score

Proposed Improvements	Score
Implement a double check system when setting the press cutter machine.	= 2(1) + 4(4) + 1(3) + 3(4) + 5(4) = 2 + 16 + 3 + 12 + 20 = 53
Create a preventive maintenance schedule for coating machines.	= 2(5) + 4(1) + 1(2) + 3(2) + 5(2) = 10 + 4 + 2 + 6 + 10 = 32

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Proposed Improvements	Score
Conduct a spray test before each coating process.	= 2(2) + 4(2) + 1(1) + 3(3) + 5(3) = 4 + 8 + 1 + 9 + 15 = 37
Tighten checks on the quality of raw materials from suppliers.	= 2(3) + 4(5) + 1(5) + 3(1) + 5(5) = 6 + 20 + 5 + 3 + 25 = 59
Perform routine cleaning of dirt on the roll.	= 2(4) + 4(3) + 1(4) + 3(5) + 5(1) = 8 + 12 + 4 + 15 + 5 = 44

After obtaining the scores for proposed improvements in the previous calculation, a final ranking is determined, prioritizing the proposed improvements that can be implemented. The final ranking for proposed improvements can be seen in the Table 16:

Table 16. Proposed Improvements

No	Proposed Improvement
1	Tighten checks on the quality of raw materials from suppliers.
2	Implement a double check system when setting the press cutter machine.
3	Perform routine cleaning of dirt on the roll.
4	Conduct a spray test before each coating process.
5	Create a preventive maintenance schedule for coating machines.

There are five priority improvements that can be implemented. The first priority improvement is to tighten the quality checks on raw materials from suppliers. The second priority improvement is to implement a double-check system when setting up the press cutter machine. The third priority improvement is to routinely clean dirt on the roll. The fourth priority improvement is to conduct a spray test before each coating process. And the fifth priority improvement is to create a preventive maintenance schedule for the coating machine.

7. Process Decision Program Chart (PDPC)

Process Decision Program Chart (PDPC) is used to identify risks and provide corrective solutions to anticipate problems and minimize the risk of failure based on the Tree Diagram that has been created [16]. There are two symbols used in the analysis: a full circle symbol, which indicates a step is possible for the company to implement, and a cross symbol, which indicates a step has a low probability of being implemented by the company. The PDPC analysis was conducted on each type of defect in the flat glass product.

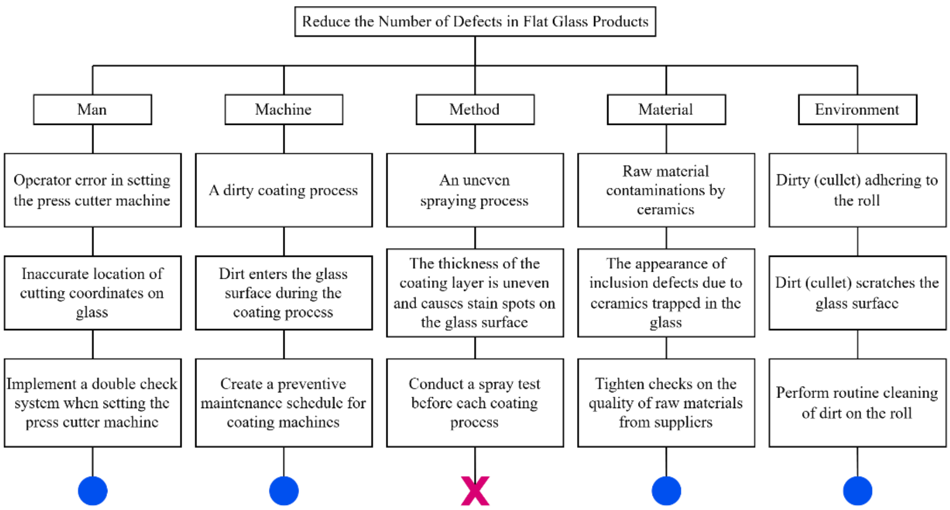

Figure 17. Process Decision Program Chart (PDPC)

To reduce the number of defects in flat glass, improvements can be proposed, namely, implementing a double check system when setting the press cutter machine for the cause of defects in the form of operator errors in setting the press cutter machine, creating a preventive maintenance schedule on the coating machine for the cause of defects in the form of a dirty coating machine, conducting routine cleaning of dirt on the roll for the cause of defects in the form of dirt (cullet) attached to the roll, and tightening checks on the quality of raw materials from suppliers for the cause of defects in the form of raw materials contaminated with ceramics. There are four improvement proposals can be implemented in the company first to reduce the number of inclusion defects. However, the improvement proposal in the form of conducting spray trials before each coating process for the cause of defects in the form of an uneven spraying process is possible to be implemented after the other four improvement proposals have been implemented by the company.

Conclusion

Based on research conducted on defects in flat glass products during the period of January - September 2025, there were 567 units, with the most dominant defect being shellchip defects at 50%, or 285 units, followed by scratch defects at 22%, or 123 units, inclusion defects at 16%, or 91 units, and stain defects at 12%, or 68 units. Then, proposed improvements that can be given to improve product quality based on priorities include tightening checks on the quality of raw materials from suppliers, implementing a double check system when setting up press cutter machines, conducting routine cleaning of dirt on rolls, conducting spray tests before each coating process, and creating a preventive maintenance schedule for coating machines.

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