THE UNIVERSITY OF DA NANG
UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF TRANSPORTATION MECHANICAL ENGINEERING

CAPSTONE PROJECT

MAJOR: INDUSTRIAL AND SYSTEMS ENGINEERING

THESIS TITLE:

Value stream improvement in the V120 department through material storage layout redesign and machining process transformation.

Supervisors: **PhD. VU THI HANH**
Engr. NGUYEN DUC PHUONG
Students: **NGUYEN HONG VAN**
HUYNH THI NGOC ANH
ID Number: **103210079**
103210062
Class: **21HTCN**

Da Nang, 6/2026

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MECHANICAL ENGINEERING

SOCIALIST REPUBLIC OF VIET NAM
Independence – Freedom – Happiness

GRADUATION THESIS ASSIGNMENT

No.	Student Names	Students ID	Class	Major
01	Nguyen Hong Van	103210079	21HTCN	Industrial and Systems Engineering
02	Huynh Thi Ngoc Anh	103210062	21HTCN	Industrial and Systems Engineering

1. *Thesis Title*

Value stream improvement in the V120 department through material storage layout redesign and machining process transformation.

2. *Type of Thesis*

Subject to an Intellectual Property Agreement regarding project outcomes

3. *Initial Data and information*

The initial data and information include:

- General information about Daiwa Vietnam Co., Ltd. and the V120 plastic injection molding department.
- Layout information of V120, including the production area, injection molding machines, raw material warehouse, and material supply route.
- Current-state data on the material supply process from V120-1 to V120-2, including distance, time, and supply frequency.
- Data on raw materials used in V120 and V120-2 for ABC analysis.
- Process data for BODY COVER 6Q4908, including operation time, Cycle Time, Lead Time, VA, NVA, and defects.
- Data for developing current-state and future-state VSMs, including material flow, information flow, and related indicators.

4. *Contents of Explanation and Calculations:*

a. General Section:

No.	Students Name	Contents
01	Nguyen Hong Van	- Learn about Daiwa Vietnam Co., Ltd., the V120 department, and the related production processes. - Identify the research objectives, research subjects, research scope, and key issues of the project. - Collect and compile general data for the current-state analysis. - Study the theoretical background and improvement tools applied in the project, such as Lean Manufacturing, VSM, ECRS, ABC Analysis, and Fishbone Diagram. - Support data processing and the development of general analytical tables and diagrams. - Propose improvement solutions to reduce waste, optimize the value stream, and enhance production efficiency in the V120 department.
02	Huynh Thi Ngoc Anh	

b. Specialized Section:

No.	Students Name	Contents
01	Nguyen Hong Van	- Analyze the current processing procedure of the BODY COVER 6Q4908 product using the drilling method. - Identify non-value-added activities such as manually breaking the gate, waiting for a complete lot, moving to the drilling area, and repeated inspection. - Propose a technology conversion plan from drilling to stamping to reduce operations,

		shorten Cycle Time, and minimize quality defects. - Develop the current-state and future-state Value Stream Maps; compare indicators before and after improvement, such as Lead Time, VA, NVA, Cycle Time, transportation distance, defect rate, and cost.
02	Huynh Thi Ngoc Anh	- Collect information on material flow, the material supply process, and the current layout in the V120-2 area. - Analyze the current material supply process from V120-1 to V120-2 for 9 injection molding machines, including travel distance, material supply time, and the number of supply trips per day. - Analyze the list of raw materials used in V120-2 using the ABC analysis method to identify the group of materials with high usage frequency. - Propose a layout plan for a temporary raw material storage area at V120-2 to reduce travel distance, material supply time, and transportation waste.

5. *Drawings, Diagrams (Specify types and dimensions of drawings clearly):*
   a. *General Section:*

No.	Students Name	Contents
01	Nguyen Hong Van	- Overview diagram of Daiwa Vietnam Co., Ltd.

02	Huynh Thi Ngoc Anh	- Organizational structure chart of the company and the V120 plastic injection molding department. - Diagram of the company's overall production operation process. - Overall layout diagram of the V120 department, including the V120-1 and V120-2 areas. - Summary table of current-state data used for improvement analysis. - Charts and summary tables presenting the project results before and after improvement.

b. Specialized Section:

No.	Students Name	Contents
01	Nguyen Hong Van	- Process flow diagram of BODY COVER 6Q4908 before improvement using the drilling method. - Process flow diagram of BODY COVER 6Q4908 after improvement using the stamping method. - Current-state and future-state Value Stream Maps of the material supply, plastic injection molding, and BODY COVER 6Q4908 processing process. - Summary table of improvement effectiveness in terms of Cycle Time, Lead Time, VA, NVA, defect rate, cost, and operational efficiency.
		- Current-state layout diagram of the material supply route from V120-1 to V120-2.

02	Huynh Thi Ngoc Anh	- Improved layout diagram after arranging a temporary raw material storage area at V120-2. - Data table of material supply time, travel distance, and number of supply trips per day. - ABC classification chart of raw materials used in V120-2. - Fishbone diagram analyzing the causes of transportation waste in the material supply process. - Comparison table of material supply distance and time before and after improvement.

6. Names of Instructors:	*Part / Contents:*
PhD: Vu Thi Hanh	All
Engr: Nguyen Duc Phuong	All

7. *Date of Thesis Assignment:* 02/27/2026
8. *Date of Thesis Completion*: 06/12/2026

Da Nang, June 12th 2026

Head of Department of Machine Design – Industrial and Systems Engineering

Supervisor

SUMMARY

Thesis title: Value stream improvement in the V120 department through material storage layout redesign and machining process transformation.

Students: Nguyen Hong Van , Huynh Thi Ngoc Anh
ID Number: 103210079, 103210062
Class: 21HTCN

Daiwa Vietnam Co., Ltd. is a subsidiary of Globeride Corporation, Japan, specializing in the manufacturing of fishing rods and reels. Through the survey conducted at the V120 plastic injection molding department, the research team identified several types of waste in the production process that reduce operational efficiency.

Currently, raw materials are stored in V120-1 but must be supplied to nine injection molding machines in V120-2, resulting in long transportation distances and high material supply time. At the same time, the BODY COVER 6Q4908 processing stage still uses the drilling method, leading to many manual operations and repeated inspections.

The main issues include:

- Transportation waste in supplying raw materials from V120-1 to V120-2.
- Lack of a temporary raw material storage area near the injection molding machines.
- Many non-value-added activities in the BODY COVER 6Q4908 processing stage.
- The drilling method increases processing time and the risk of quality defects.

This project applies Value Stream Mapping (VSM) combined with Lean Manufacturing, ECRS, ABC Analysis, and Fishbone Diagram to analyze the current state and propose improvement solutions. The two main solutions are arranging a temporary raw material storage area at V120-2 and converting the BODY COVER 6Q4908 processing method from drilling to stamping.

The objective of this project is to reduce transportation time, shorten Cycle Time and Lead Time, reduce waste, improve product quality, and enhance production efficiency in the V120 department.

ACKNOWLEDGEMEMTS

Through the capstone project entitled “Value Stream Improvement in the V120 Department through Material Storage Layout Redesign and Machining Process Transformation,” our team had the opportunity to apply the knowledge acquired during our studies to a real manufacturing environment at Daiwa Vietnam Co., Ltd. In addition, we gained valuable experience in on-site observation, data collection, value stream analysis, and the development of improvement solutions.

To complete this capstone project, we would like to express our sincere gratitude to Dr. Vu Thi Hanh for her dedicated guidance, valuable advice, and continuous support throughout the project. We would also like to extend our heartfelt thanks to Mr. Nguyen Duc Phuong at Daiwa Vietnam Co., Ltd. for his direct assistance, guidance, and support during our internship, site surveys, and data collection process. Furthermore, we would like to express our appreciation to all lecturers of the Machine Design – Industrial Engineering and Systems Department for their dedication and invaluable knowledge shared throughout our academic journey.

Due to limitations in time, knowledge, and practical experience, this capstone project may still contain certain shortcomings. We sincerely welcome comments and suggestions from our lecturers to help us improve and further develop our professional capabilities.

Once again, we would like to express our deepest gratitude to everyone who supported us throughout this project.

Da Nang, June 23th 2026

TABLE OF CONTENTS

ACKNOWLEDGEMEMTS ..... **i**

TABLE OF CONTENTS ..... **ii**

LIST OF FIGURES ..... **vi**

LIST OF TABLES ..... **ix**

ABBREVIATIONS ..... **xi**

Chapter 1: Overview and Introduction to the Project **1**

1.1. General Introduction to the Project **1**

1.2. Overview of Daiwa Vietnam Co., Ltd. and the V120 Department **1**

1.2.1. General information *1*

1.2.2. History and Development *3*

1.2.3. Business Fields and Products *4*

1.2.4. Organizational Structure and Functions of Relevant Departments *6*

1.2.5. Company's Production Operation Model *8*

1.2.6. Scale and Operational Structure of the V120 Department *11*

1.2.7. Parts in the V120 Plastic Injection Molding Department *12*

1.3. Identification of Current-State Problems **14**

1.4. Research Objectives, Subjects, and Scope **15**

Chapter 2: Basic Theory of Value Stream Optimization in Manufacturing **18**

2.1. Overview of Lean Manufacturing **18**

2.2. Time Indicators in Production Analysis **18**

2.2.1. Talk Time *18*

2.2.2. Cycle Time *18*

2.2.3. Lead Time *19*

2.2.4. Changeover Time *19*

2.2.5. Available Production Time *19*

2.2.6. Value – Added Time *19*

2.2.7. Non – Value – Added Time *19*

2.3. Types of Waste in Manufacturing **20**

2.4. Value Stream Mapping **21**

2.4.1. Value Stream Mapping Tools *21*

2.4.2. Steps to Create a Value Stream Mapping *23*

2.4.3. Suitability of VSM for This Study *25*
2.5. Fishbone Diagram **25**
2.6. ECRS Method **26**
2.7. ABC Classification in Material Management **27**
2.7.1. ABC Classification Formula *28*
2.7.2. Importance of ABC Classification for the Material Staging Area *28*
2.8. Production Layout **28**
2.8.1. Objectives of Production Layout *29*
2.8.2. Lean Principles of Production Layout *29*
2.8.3. Selection Criteria and Application of the Material Staging Area *30*
2.9. Post-Molding Processing Technology: Drilling and Gate Stamping **31**
2.9.1. Principle of Drilling for Gate Processing *31*
2.9.2. Principle of Stamping for Gate Processing *32*
2.9.3. Comparison Between Drilling and Stamping for Gate Processing *32*
2.9.4. Conditions for Changing from Drilling to Stamping *33*
Chapter 3: Current Situation Analysis at the V120 Department **35**
3.1. Description of the Current Production System at the V120 Department **35**
3.2. Data Collection and Analysis Methods **35**
3.3. Analysis of the Current Layout and Material Supply Activities at V120 ..... **36**
3.3.1. Current Layout *36*
3.3.2. Measurement of Material Supply Time and Transportation Distance *40*
3.4. Analysis of Material Usage at V120-2 ..... **43**
3.4.1. List of Materials Used at V120-2 ..... *43*
3.4.2. Analysis of Materials Used in the V120-2 Area *44*
3.5. Analysis of the Manufacturing Process of BODY COVER 6Q4908 ..... **46**
3.5.1. Introduction of BODY COVER 6Q4908 ..... *46*
3.5.2. Current Manufacturing Process *47*
3.5.3. Current Drilling Process for Gate Processing *53*
3.5.4. Actual Cycle Time of the BODY COVER 6Q4908 Manufacturing Process *57*
3.6. Current Value Stream Mapping of the V120 Department **58**
Chapter 4: Future-State Value Stream Design and Proposed Improvement Solutions **63**

4.1. Layout Improvement for the Temporary Raw Material Storage Area at V120-2 63

4.1.1. Basis and Objectives of the Proposed Solution 63

4.1.2. Calculation of the Required Area for the Temporary Raw Material Storage Area at V120-2 64

4.1.3. Determination of Storage Requirements and Temporary Raw Material Pallet Arrangement at V120-2 65

4.1.4. ABC Analysis of Raw Materials at V120-2 67

4.1.5. Measurement of Material Supply Time and Distance after Improvement 70

4.1.6. Layout after Improvement 72

4.2. Processing Technology Conversion 73

4.2.1. Study on the Feasibility of Converting Film Gate Processing Technology from Drilling to Stamping for BODY COVER 6Q4908 73

4.2.2. Conditions for Applying the Stamping Method 75

4.2.3. Periodic Maintenance Standards for Punches, Dies, and Stamping Jigs 80

4.2.4. Post-Improvement Gate Stamping Process 81

4.3. Development of the Future State Value Stream Map for the V120 Department 85

4.3.1. Basis for Developing the Future State VSM 85

4.3.2. Cycle Time After Improvement of the BODY COVER 6Q4908 Production Process 87

4.3.3. Material Flow in the Future State VSM of the V120 Department 88

4.3.4. Wastes Eliminated or Reduced in the Future State VSM 90

Chapter 5: Evaluation of Value Stream Improvement Effectiveness in the V120 Department 92

5.1. Evaluation of the layout improvement for the temporary raw material storage area at V120-2 92

5.1.2. Comparison of Material Supply Time Before and After Improvement ... 94

5.2. Evaluation of the Improvement Effectiveness of the BODY COVER 6Q4908 Processing Stage from Drilling to Stamping 96

5.2.1. Comparison of Operation Process and Cycle Time Before and After Improvement 98

5.2.2. Product Quality Evaluation after Converting to the Stamping Method . 99

5.2.3. Evaluation of Safety and Ergonomics Factors 103

5.3. Evaluation of Value Stream Improvement through Comparison of Current-State and Future-State VSMs 105

5.4. Economic Evaluation of the Improvement Solutions 106

5.4.1. Economic Benefits of Establishing a Satellite Warehouse/Temporary Raw Material Storage Area at V120-2.....107

5.4.2. Economic Benefits of Converting the Processing Technology from Drilling to Stamping.....110

5.4.3. Summary of the Economic Benefits of the Two Improvement Solutions 113

5.5. Limitations of the Project and Expansion Potential.....114

5.5.1. Limitations of the Study.....114

5.5.2. Applicability to Other Part Numbers.....115

5.5.3. Future Improvement Directions.....117

REFERENCES.....119

LIST OF FIGURES

Figure 1.1. Logo of Daiwa Vietnam Co., Ltd. 1

Figure 1.2. Factory layout diagram of Daiwa Vietnam Co., Ltd. 2

Figure 1.3. Headquarters of Daiwa Vietnam Co., Ltd. in Da Nang.....3

Figure 1.4. Business Operations and Representative Products 5

Figure 1.5. Organizational Structure Chart of Daiwa Vietnam Co., Ltd. 6

Figure 1.6. Organizational Structure of the V120 Department.....11

Figure 1.7. Layout Diagram of the V120 Department 12

Figure 1.8. Representative Parts in the V120 Plastic Injection Molding Department 13

Figure 2.1. Steps to Create a Value Stream Mapping 23

Figure 2.2. Illusrate the Fishbone Diagram.....26

Figure 2.3. Gate location and Film Gate requiring processing on the BODY COVER 6Q4908 product.....31

Figure 3.1. Current Layout of the V120 Department.....38

Figure 3.2. V120 Machine Layout 39

Figure 3.3. Fishbone Diagram of Transportation Waste Causes in the Material Supply Process at V120-2. 42

Figure 3.4. Raw Material Usage Data in the V120-2 Area.....44

Figure 3.5. Material Output by Machine at V120-2 Area.....45

Figure 3.6. Fishbone Diagram of the Causes of Processing Waste in the BODY COVER 6Q4908 Process 56

Figure 3.7. Current-State Value Stream Map (VSM) of Material Supply and Manufacturing Flow for BODY COVER 6Q4908 61

Figure 4.1. Arrangement of temporary raw material pallet locations at V120-2.....65

Figure 4.2. Pareto Chart of Raw Material Consumption at V120-2 68

Figure 4.3. Transportation of Raw Materials from the V120-1 Warehouse to V120-2.....**Error! Bookmark not defined.**

Figure 4.4. Temporary Raw Material Storage Area for Production at V120-2 after Improvement .....**Error! Bookmark not defined.**

Figure 4.5. Layout of the V120 Department after Improvement 72

Figure 4.6. Product gate 76

Figure 4.7. Product gate after robot cutting: 18 mm < gate relief hole length of the punch: 20 m.....76

Figure 4.8. Film Gate requiring processing **Figure 4.9**. The actual thickness is 1,5 mm; therefore, stamping is feasible 77

Figure 4.10. The required processing dimension is $Ø13^{+0,2}_{0}$ mm. 77

Figure 4.11. Design the punch and die dimensions to match the required processing dimension. 78

Figure 4.12. Prepare a manufacturing request form for the stamping jig 79

Figure 4.13. Stamping Jig 79

Figure 4.14. Stamping Jig **Figure 4.15.** Stamping machine 82

Figure 4.16. Place the product into the stamping jig.....83

Figure 4.17. Gate stamping operation 83

Figure 4.18. Operation of removing the product from the stamping jig 84

Figure 4.19. Visual inspection of the product 84

Figure 4.20. Place the product into the basket 84

Figure 5.1. Chart Comparing Material Supply Distance Before and After Improvement 93

Figure 5.2. Chart comparing material supply time before and after improvement..95

Figure 5.3. Comparison of Cycle Time Before and After Improvement.....99

Figure 5.4. Current State of BODY COVER 6Q4908 Placed on the Drilling Jig .100

Figure 5.5. Risk of Film Gate tearing, deformation, or burr formation at the Film Gate position during drilling 100

Figure 5.6. Stamping Jig Used for Processing the Gate of the BODY COVER 6Q4908 Product 101

Figure 5.7. BODY COVER 6Q4908 Product after Processing by the Stamping Method 102

Figure 5.8. Comparison of Lead Time, VA Time, and NVA Time between Current-State and Future-State VSMs 106

LIST OF TABLES

Table 1.1. History and Development of Daiwa Vietnam Co., Ltd. 3

Table 1.2. Current-state baseline data for evaluating improvement at the V120 department 15

Table 1.3. Research Subjects of the Capstone Project 16

Table 2.1. Value stream mapping tools 21

Table 2.2. Comparison Between Drilling and Stamping for Gate Processing 32

Table 3.1. List of Materials Used in the V120 Area 43

Table 3.2. Summary of Material Usage Output by Machine in Area V120-2 (March, April, May 2025) 45

Table 3.3. ECRS Analysis of the BODY COVER 6Q4908 Production Process 47

Table 3.4. Process Steps and Visual Illustrations of the Actual Production Process. 48

Table 3.5. Actual Cycle Time of the BODY COVER 6Q4908 Manufacturing Process 57

Table 3.6. Summary of Data Used for Current State Value Stream Mapping in the V120 Department 59

Table 4.1. Raw Material Usage Table for March 2026 66

Table 4.2. ABC Analysis Results of Raw Materials at V120-2 68

Table 4.3. Proposed Pallet Allocation for the Material Waiting Area at V120-2 69

Table 4.4. Measurement of Material Supply Time and Distance after Improvement 70

Table 4.5. Summary of Punch Tip and Punch Pin Specifications for the BODY – BODY COVER Product Group 73

Table 4.6. List of Part Numbers Currently Processed by the Drilling Method 74

Table 4.7. Post-Improvement Gate Stamping Operation Steps 81

Table 4.8. Cycle Time After Improvement of the BODY COVER 6Q4908 Production Process 87

Table 5.1. Comparison of Material Supply Distance Before and After Improvement 93

Table 5.2. Comparison of Material Supply Time Before and After Improvement..95

Table 5.3. Pre-Improvement Operation Procedure 96

Table 5.4. Post-Improvement Operation Procedure.....97

Table 5.5. Comparison of Cycle Time Before and After Improvement 98

Table 5.6. Comparison of BODY COVER 6Q4908 Product Quality Before and After Improvement 102

Table 5.7. Comparison between Current-State and Future-State VSMs.....105

Table 5.8. Equivalent Manpower Reduction.....108

Table 5.9. Comparison of Material Supply Cost Before and After Improvement.109

Table 5.10. Comparison of Process Cost Before and After Improvement.....111

Table 5.11. Tooling Cost Saving After Converting from Drilling to Stamping 112

Table 5.12. Specifically summarizes the savings of each improvement solution..113

ABBREVIATIONS

ABBREVIATIONS	FULL LETTERS
VSM	Value Stream Mapping
CO	Changeover Time
CT	Cycle Time
VA	Value Added Time
NVA	Non-Value-Added Time
APT	Available Production Time
AOP	Actual Operating Time
UP	Uptime
OP	Operator
OEE	Overall Equipment Effectiveness
ABC	ABC Analysis
5S	Sort – Set in order – Shine – Standardize – Sustain
ECRS	Eliminate – Combine – Rearrange – Simplify
IE	Industrial Engineering
FIFO	First In, First Out
NG	No Good
QA	Quality Assurance
QC	Quality Control

Chapter 1: Overview and Introduction to the Project

1.1. General Introduction to the Project

In manufacturing operations, optimizing material flow and reducing non-value-added activities play an important role in improving productivity, shortening production time, and reducing operating costs. For plastic component manufacturing enterprises, activities such as raw material supply, internal transportation, post-molding processing, and product inspection, if not properly arranged, may generate various types of waste, directly affecting Lead Time and production efficiency.

At the V120 plastic injection molding department of Daiwa Vietnam Co., Ltd., the current production flow includes the following main stages: raw material storage, raw material supply, plastic injection molding, post-molding processing, and transfer to the next process. During operation, two major issues currently exist in the V120 area. The first issue is that raw materials are mainly stored in the V120-1 area but still need to be supplied to injection molding machines in V120-2, resulting in long and repeated transportation distances. The second issue is that the BODY COVER 6Q4908 processing stage still uses the gate drilling method, leading to many manual operations, additional movement to the drilling area, and the risk of quality defects.

Based on this actual situation, the topic **"Value stream improvement in the V120 department through material storage layout redesign and machining process transformation."** was selected for this study. The project focuses on analyzing the current value stream in the V120 department, identifying waste in the material supply process and post-molding processing stage, and then proposing improvement solutions to reduce non-value-added time, shorten Lead Time, and improve operational efficiency.

1.2. Overview of Daiwa Vietnam Co., Ltd. and the V120 Department

1.2.1. General information

Figure 1.1. Logo of Daiwa Vietnam Co., Ltd.

Daiwa Vietnam Co., Ltd. belongs to Globeride Group, a Japanese corporation headquartered in Higashikurume, Tokyo, Japan, specializing in the manufacturing and business of fishing equipment, tennis equipment, golf equipment, bicycles, …

Business field: Manufacturing fishing rods and fishing reels.

Address: Lot M, Street No. 5, Hoa Khanh Industrial Park, Hoa Khanh Bac Ward, Lien Chieu District, Da Nang City.

Established date: September 19, 2005. Business license issued on September 15, 2006.

Number of workers: Approximately 4.000 workers.

The company consists of three factories with a total area of 117.000 m², including:

- REEL No. 1 Factory: 60.000 m².
- REEL No. 2 Factory: 17.000 m².
- ROD Factory: 40.000 m².



Figure 1.2. Factory layout diagram of Daiwa Vietnam Co., Ltd.

GLOBERIDE operates a global manufacturing network with production facilities located in Japan, Vietnam, Thailand, China, and the United Kingdom, in which Daiwa Vietnam Co., Ltd. plays an important role in the corporation's global supply chain. In addition, the group maintains an extensive network of distributors and sales offices across many countries, enabling Daiwa to expand its presence in international markets.

With advanced technology, high product quality, a widespread manufacturing network, and a commitment to sustainable development, Daiwa has established itself

as one of the world's leading brands in the fishing equipment and outdoor sports industries.

Following the philosophy of placing community benefits at the center of its operations, Daiwa Da Nang continuously seeks and implements solutions to improve production efficiency, reduce product costs, and enhance environmental protection. The company consistently invests in infrastructure development, factory expansion, and modern manufacturing equipment while applying advanced scientific and technological achievements to its production processes. Its smart factory system increases technological integration and automation levels, thereby ensuring that product quality consistently meets the highest standards.



Figure 1.3. Headquarters of Daiwa Vietnam Co., Ltd. in Da Nang

1.2.2. History and Development

Table 1.1. History and Development of Daiwa Vietnam Co., Ltd.

Time	Description
September 2005	Received Investment License No. 36/QP.KCN.DNg.
November 2005	Established a temporary office in Da Nang.
January 2006	Conducted Japanese language training for employees.

Time	Description
March 2006	Phase 1 started, constructing the first factory with an area of 2 hectares.
September 2006	Completed construction of Factory A and began production, exporting the first shipment to the U.S. market.
April 2007	Started PMC production for the U.S. market and fishing rod production for the Japanese market.
June 2007	Began Phase 2 construction, including Factories B and C.
July 2007	Conducted the second Japanese language training course for employees.
November 2007	Started mass production of fishing rods and fishing reels for the Japanese market.
May 2008	Completed Phase 2 construction of Factories B and C.
June 2008	Began reel production at Factory C and exported products to North American, Asian, and European markets.
February 2015	Started operation of the mold manufacturing factory.
June 2018	Started operation of the machining factory.
December 2019	Started operation of the new plating factory.
April 2022	Started operation of the eco-friendly fishing rod manufacturing factory.

1.2.3. Business Fields and Products

Daiwa Vietnam Co., Ltd. operates in the field of manufacturing and trading sports equipment and plays an important role in the global supply chain of Globeride Group. The company's main product groups include fishing equipment, tennis equipment, golf equipment, and sports bicycles, serving many international markets.

Among them, Daiwa-branded fishing products are the company's core business, meeting the needs of the fishing industry worldwide. In addition, the company also manufactures and processes other sports products such as tennis rackets, golf clubs, and bicycles, which require high quality, technical precision, and consistency in production.

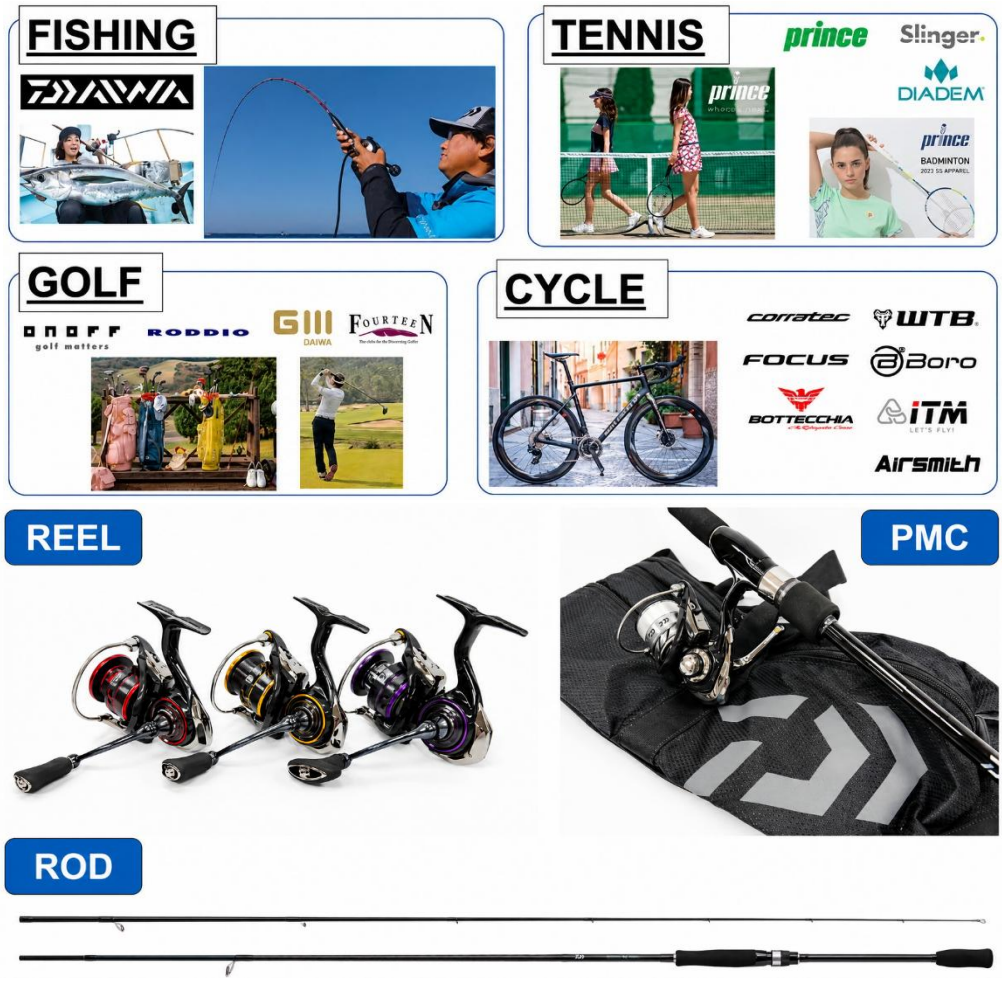


Figure 1.4. Business Operations and Representative Products

1.2.4. Organizational Structure and Functions of Relevant Departments

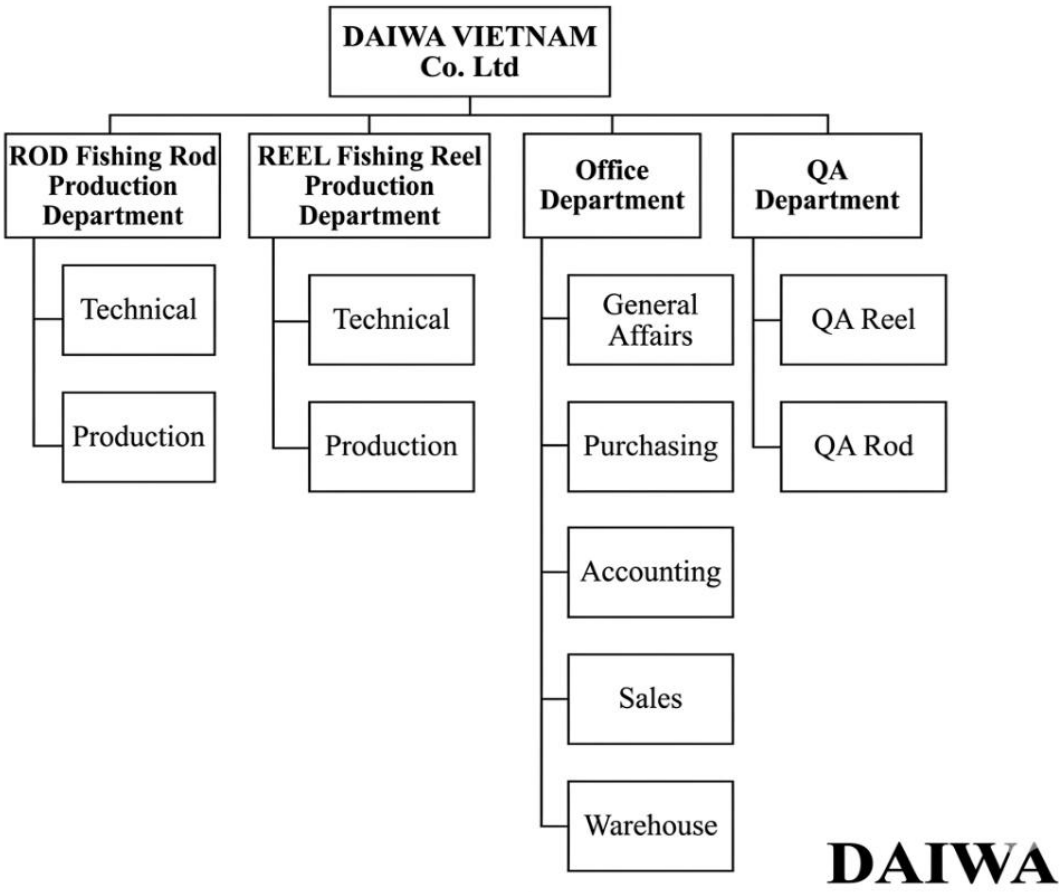


Figure 1.5. Organizational Structure Chart of Daiwa Vietnam Co., Ltd.

The Board of Directors is responsible for the overall management and operation of the company, making decisions on factory-related matters, and bearing the highest responsibility to the government, employees, and for the factory's business performance.

Under the direct management of the Board of Directors, there are four main departments:

- ROD fishing rod production department
- REEL spinning reel production department
- Office department
- QA department

a) ROD Fishing Rod Production Department

This department is responsible for fishing rod production and includes the Rod Production Department and the Rod Engineering Department.

- Engineering Department:

- Ensures technical requirements, conducts trial production, and adjusts designs to suit actual production conditions and customer requirements before mass production.
- Includes Production Engineering V291, Product Engineering V239, and Design V296.

- Production Department:

- Prepares production plans and directly participates in fishing rod production.
- Participates in fishing rod manufacturing, including the following sections: Fabric Rolling V220, Finishing V230, Painting V240, Assembly V260, Packing V270, EVA Grip V266, and Parts Marking V265.

b) REEL Production Department

This department is responsible for producing fishing reels and includes the Reel Production Department and the Reel Engineering Department.

- Engineering Department:

- Ensures technical requirements, conducts trial production, and adjusts designs to suit actual production conditions and customer requirements before mass production.
- Includes Production Engineering V191, Product Engineering V193, Design V195, and Mold V197.

- Production Department:

- Prepares production plans and directly participates in reel production.
- Participates in reel manufacturing, including the following sections: Plastic Injection Molding V120, Stamping V125, Metal Casting V135, Reel Machining V130, Reel Painting V140, Anodizing V145, Plating V155, and Reel Assembly V160.

c) Office Department

This is a non-production department responsible for administrative and office-related tasks. The Office Department is divided into several smaller sections, such as General Affairs, Accounting, Reel Purchasing, Rod Purchasing, and Import-Export. Each section has its own functions and duties according to its professional role:

- REEL Purchasing Department: Manages materials and places purchase orders for Reel-related items based on purchase request plans from the production management department.
- ROD Purchasing Department: Manages materials and places purchase orders for Rod-related items based on purchase request plans from the production management department.
- General Affairs Department: A specialized department that assists the Center Director in implementing tasks related to organization and administration, planning and general affairs, and financial activities of the company.
- Accounting Department: Records, collects, provides, and processes financial information, and prepares financial reports for internal company operations as well as external agencies such as tax authorities and banks.
- Import-Export Department: Responsible for coordinating and supervising supply chain activities, ensuring that company assets are used effectively, and applying logistics technology to optimize the transportation process.

d) Quality Assurance Department

The departments coordinate smoothly to ensure the company's production and business operations, maintain the quality of fishing rods and reels, and prevent defective products from reaching customers. This department includes:

- QA Reel V180: Controls the quality of reel products at the Reel factory.
- QA Rod V280: Controls the quality of fishing rod products at the Rod factory.

1.2.5. Company's Production Operation Model

Responsibility	Flowchart (Sequence of work)	Documents / Records
Sales Departmen	**Receive order data** ⬇	Save on the computer. O serve/1. REEL DEPARTMENT/16.PRODUCTION
Production Management Department	**Production planning** ⬇	DVF-110-B-001

Responsibility	Flowchart (Sequence of work)	Documents / Records
Production Management Department	**Material calculation Capacity check: Machinery, Equipment, and Personnel** ⬇	Save on the computer. O serve/1.REEL DEPARTMENT/08. Capacity & 06.Material
Heads of Production Departments / Production Management Staff / Department Technical Staff	**Implement the production plan** ⬇	Save on the computer. O serve/1.REEL DEPARTMENT/07.schedule/02.Factory
Heads of Production Departments / Production Management Staff / Department Technical Staff	**Production Control** ⬇	Department Inspection Form (Daily Report)
QA (Product Quality Assurance)	**QA Check** ⬇	QC/QA Inspection Form (Daily Report)
Heads of Production Departments / Production Management Staff / Department Technical Staff	**Store records** ⬇	Department Inspection Form (Daily Report)
Heads of Production Departments / Production Management Staff / Department Technical Staff	**Factory Dispatch**	Department Inspection Form (Daily Report)

- **Receiving order data**

Every month, the Sales Department receives customer orders in accordance with the company's regulations. Orders are received four months before production to ensure sufficient preparation time. All order data is stored on the shared drive of the server system so that relevant departments can access and process it.

- **Production planning**

After receiving order data from the Sales Department, the Production Management Department prepares the production plan. The production plan is developed based on information such as product type, quantity, delivery deadline,

and the factory's production capacity. The plan is prepared monthly and follows the prescribed company format.

- **Calculating raw materials and production capacity**

The Production Management Department is responsible for calculating raw material requirements, machinery and equipment capacity, and manpower based on the issued production plan. The calculation is carried out based on the standard time for each manufactured component. The calculation results are prepared four months in advance and sent to the production departments for checking, balancing, and agreement.

- **Requesting raw material purchase, warehousing, and inspection**

Based on the production plan and raw material calculation results, the Production Management Department prepares a raw material purchase request and sends it to the Purchasing Department. The request must include complete information on the type of raw material, quantity, and delivery schedule. After the raw materials are purchased, the Warehouse Department carries out warehousing and inspection in accordance with the company's prescribed procedures

- **Implementing the production process**

After the production plan is approved by the Factory Director, the Production Management Department sends the plan to the production departments. The departments carry out production according to the issued plan information, such as production lot number, model, quantity, and delivery deadline, ensuring that both schedule and product quality requirements are met.

1.2.6. Scale and Operational Structure of the V120 Department

Department management structure chart:

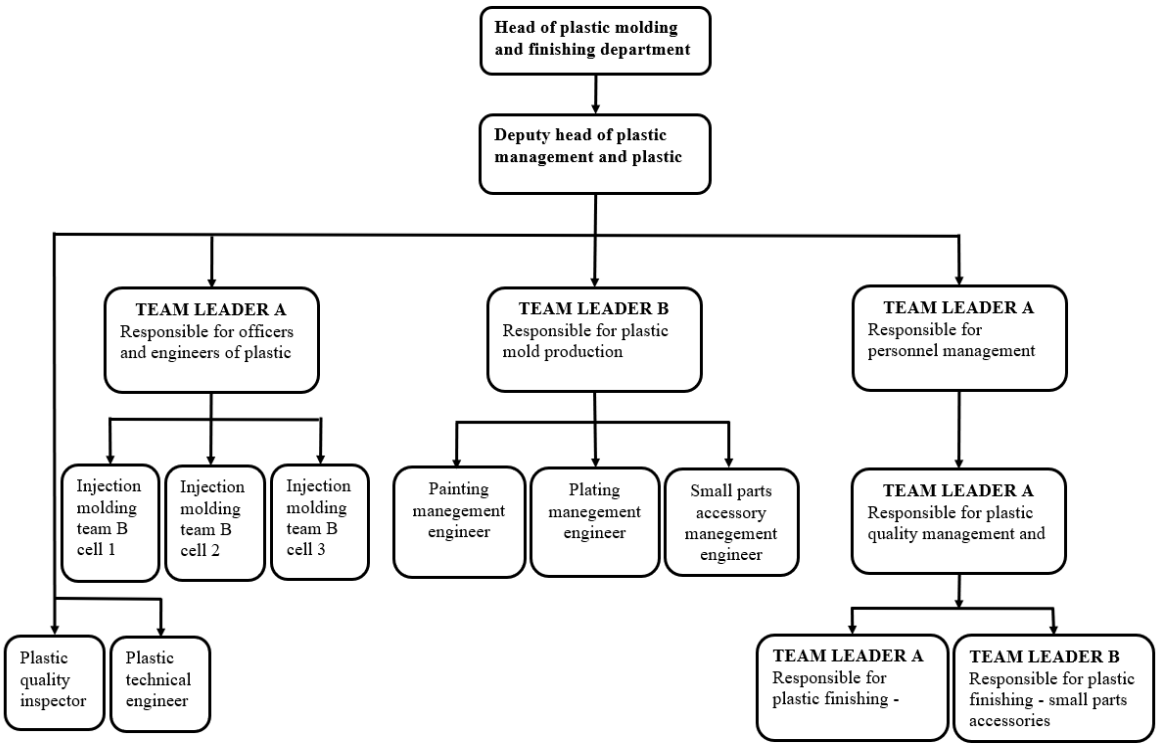


Figure 1.6. Organizational Structure of the V120 Department

The diagram above shows the organizational structure of the department responsible for plastic injection molding and plastic molding finishing. The department is headed by the Department Manager, who is responsible for overall production activities, personnel management, and plastic molding finishing. Under the Department Manager is the Assistant Department Manager, whose role is to support operations and directly manage activities related to production and engineering in the plastic injection molding area.

The second group is led by Team Leader B, who is responsible for production management in the plastic injection molding department. This group is related to production support areas such as painting management, plating management, and accessories/small parts management. These support sections ensure that the production and finishing processes of plastic products are carried out according to technical requirements.

The third group is the quality control and plastic molding finishing management section. In this group, Team Leader A is responsible for plastic quality management,

together with teams in charge of painted component finishing and small component finishing. This group plays a role in controlling product quality after molding, handling finishing processes, and ensuring that products meet requirements before being transferred to the next process.

This model helps clearly assign responsibilities among departments, supports product quality control, and improves production management efficiency.

- Production area: Approximately 3.000 m².
- Structure of two production workshops: V120-1 and V120-2.

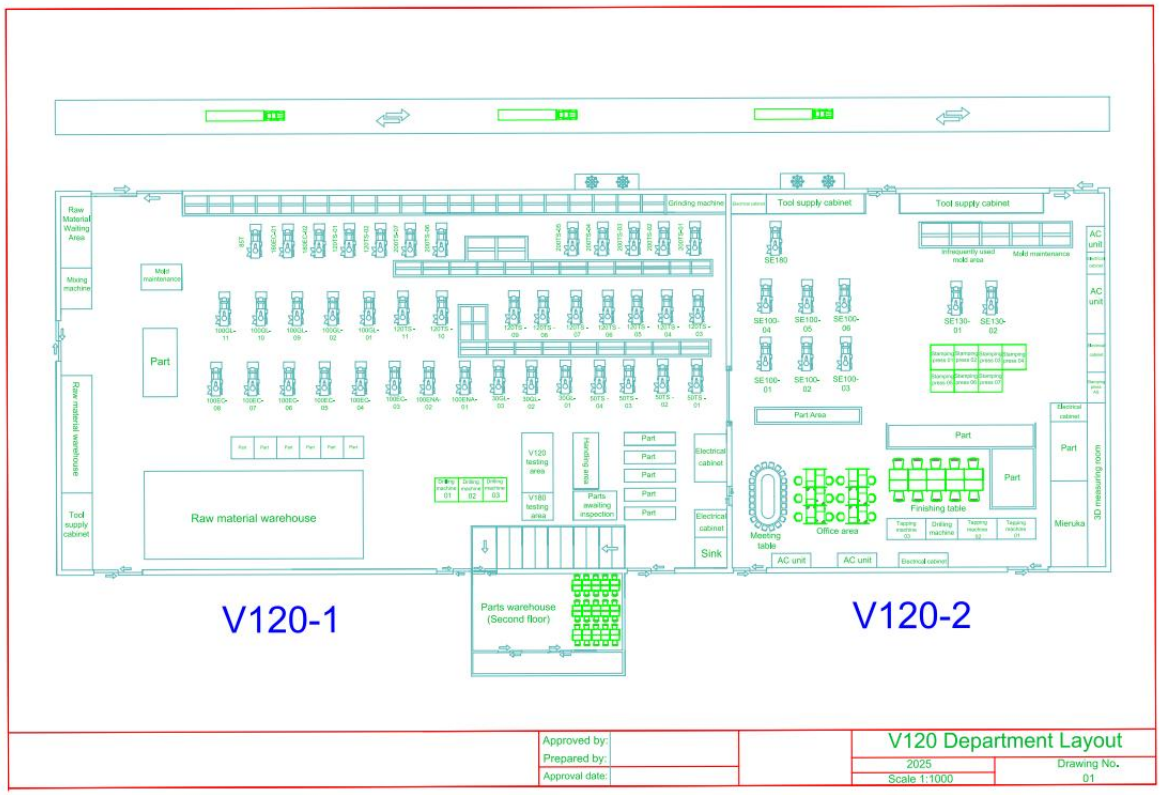


Figure 1.7. Layout Diagram of the V120 Department

1.2.7. Parts in the V120 Plastic Injection Molding Department

Part Name	Image
a. Body	

Part Name	Image
b. Body cover	
c. Rotor	
d. Handle Arm	
e. Linh kiện nhỏ	

Figure 1.8. Representative Parts in the V120 Plastic Injection Molding Department

The parts in the V120 plastic injection molding department are plastic components of the reel assembly, manufactured using the plastic injection molding method. Products such as Body, Body Cover, Rotor, Handle Arm, and several small parts play an important role in forming the structure, appearance, and function of the finished product. Among them, Body and Body Cover are usually main parts that require dimensional accuracy, assembly stability, and high surface quality. Rotor and Handle Arm are related to the movement mechanism of the reel, requiring molded products to ensure proper shape, strength, and surface quality. Although small parts are not large in size, they still play a supporting role in the assembly and product finishing process. Therefore, the plastic injection molding process at V120 must be strictly controlled in terms of materials, molding conditions, post-molding operations, and product quality in order to reduce defects and ensure production efficiency.

1.3. Identification of Current-State Problems

The V120 plastic injection molding department currently operates through the following sequence of activities: raw material warehouse → raw material supply → processing → finished products. Within this sequence, the study identifies two main issues affecting production efficiency: transportation waste in the material supply process and motion waste in the processing stage.

First, regarding the material supply process, the V120 area consists of two production workshops: V120-1 and V120-2. V120-1 has 35 injection molding machines, while V120-2 has 9 injection molding machines, with a total of 44 machines. Currently, raw materials are mainly stored in the warehouse located in V120-1 but still need to be supplied to the injection molding machines in V120-2. This results in long travel distances repeated many times during the day, causing time and manpower consumption and generating non-value-added activities.

Second, in the BODY COVER 6Q4908 processing stage, the current process still includes manual operations such as manually breaking the gate, moving to the drilling area, and performing post-molding drilling. These operations do not directly add significant value to the product but increase operation time, cause worker fatigue, and pose a potential risk of quality defects.

From the current situation above, it can be seen that the value stream at V120 has not yet been optimized. Material transportation and post-molding processing activities still have several unreasonable points, increasing non-value-added time, extending Lead Time, and affecting the overall productivity of the department.

To avoid subjective evaluation of the current state, the study collected several initial data as a basis for comparison before and after improvement. These data are considered the current-state baseline, reflecting the time, distance, frequency, and operations currently occurring in the existing process. This baseline serves as the basis for identifying the level of waste and evaluating the effectiveness of improvement solutions in the following chapters.

Table 1.2. Current-state baseline data for evaluating improvement at the V120 department

Measurement item	Collected current state	Purpose of use
Material supply time from V120-1 to V120-2	Average 221,2 seconds/time/machine; total 5.973 seconds/day (99,55 minutes/day)	Basis for before-and-after improvement comparison
Number of material supply trips per day for 9 machines in V120-2	27 times/day	Calculate total wasted time per day
Travel distance per trip	Total 4.022,4 m/day; average 74.49 m one way/machine	Calculate total transportation distance per day
Drilling processing time for BODY COVER 6Q4908	Cycle Time: 62,8 seconds/product; movement to the drilling area: 180,1 seconds/time	Compare with the stamping method
Defect rate or defects occurring in the drilling process	1,2%, equivalent to 518/43.158 products/year	Evaluate quality impact

Therefore, the capstone project **"Value stream improvement in the V120 department through material storage layout redesign and machining process transformation."** was selected for this study.

1.4. Research Objectives, Subjects, and Scope

a) Research Objectives

The objective of this capstone project is to optimize the value stream in the V120 plastic injection molding department through two main improvement solutions: establishing a temporary raw material storage area at V120-2 and converting the processing technology for the BODY COVER 6Q4908 product from drilling to stamping.

The project focuses on analyzing the current-state value stream of the V120 plastic injection molding department, with particular emphasis on the raw material supply process for the V120-2 area and the post-molding processing operation of the BODY COVER 6Q4908 product. Based on the collection and analysis of actual shop-floor data, such as material supply distance, material supply time, number of supply trips per day, processing time, number of operation steps, and defect rate, the study identifies non-value-added activities within the current process. Appropriate improvement solutions are then proposed to reduce transportation waste, minimize manual operations, shorten Lead Time, and improve operational efficiency in the V120 department.

For the material supply process, the project aims to reduce the transportation distance and material supply time from V120-1 to V120-2 for nine injection molding machines. The evaluation criteria include material supply distance, material supply time per trip, number of supply trips per day, and total material supply time per day. For the processing operation, the project focuses on improving the BODY COVER 6Q4908 product by replacing the drilling method with the stamping method to reduce manual operations, shorten processing time, and minimize defects.

After implementation, the effectiveness of the improvements will be evaluated by comparing key performance indicators before and after improvement, including transportation distance, material supply time, processing time, number of operations, Lead Time, productivity, and operating cost. Quantitative targets will be determined based on actual shop-floor measurements, such as reducing material supply time from X minutes per trip to Y minutes per trip, reducing transportation distance from A meters per trip to B meters per trip, or reducing processing time from M seconds per product to N seconds per product.

b) Research Subjects

The research subjects of this project are as follows:

Table 1.3. Research Subjects of the Capstone Project

Research Subject	Description
Production area	Injection molding machines at V120-2
Number of machines	9 injection molding machines
Material flow	Plastic resin supplied from V120-1 to V120-2

Research Subject	Description
Product selected for processing analysis	BODY COVER 6Q4908
Improvement processes	Material supply and post-molding processing
Analysis tools	VSM, Lean, ECRS, layout analysis, and work measurement (method and time study)

c) Research Scope

This project is conducted in the V120 plastic injection molding department, focusing on material flow and post-molding processing operations. The study primarily focuses on the V120-2 area, where nine injection molding machines are supplied with raw materials from V120-1.

The research consists of two main areas:

Warehouse and material supply process: Investigating the current material supply process from V120-1 to V120-2, analyzing transportation distance, material supply time, supply frequency, and the feasibility of establishing a temporary raw material storage area at V120-2.

Processing operation: Investigating the finishing process of the BODY COVER 6Q4908 product, focusing on gate breaking operations, movement to the drilling area, and the conversion from drilling to stamping.

d) Research Limitations

This project only addresses two major issues: the establishment of a temporary raw material storage area at V120-2 and the conversion of the processing technology from drilling to stamping. The study does not cover the raw material drying system, the central warehouse, a complete factory layout redesign, or expansion to all product models within the department. Data were collected during the period from January 1, 2026, to April 15, 2026, to reflect the actual material supply and processing conditions at the time of the study.

Chapter 2: Basic Theory of Value Stream Optimization in Manufacturing

2.1. Overview of Lean Manufacturing

Lean Manufacturing is a production management approach that aims to maximize customer value by using resources efficiently and eliminating non-value-added activities in the production process. Unlike traditional approaches that focus on individual operations, Lean emphasizes the analysis of the entire flow of materials and information from input to output to identify sources of waste, interruptions, and factors that increase production lead time.

The implementation of Lean Manufacturing helps companies improve productivity, maintain stable product quality, reduce operating costs, and increase the flexibility of production processes. Among these factors, time plays an important role because it directly reflects the efficiency of the production flow. Several key indicators commonly used in Lean analysis include Cycle Time (CT), Takt Time, Changeover Time (CO), and Available Production Time (APT). These indicators provide a basis for evaluating the current situation, identifying inefficiencies, and proposing appropriate improvement solutions.

2.2. Time Indicators in Production Analysis

2.2.1. Talk Time

Takt Time is the time required to produce one product according to customer demand. It is used to determine the production rate needed to meet customer requirements. Calculating Takt Time helps identify how many products should be produced within a given period to satisfy customer demand. Therefore, Takt Time is an important indicator for optimizing production processes and improving production efficiency. Mathematically, Takt Time is calculated by dividing the available production time by customer demand.

$$Talk\ Time\ = \frac{Available\ Production\ Time}{Customer\ Demand}$$

2.2.2. Cycle Time

Cycle Time (CT) is the time required to complete one product or one unit of work, measured from the beginning to the completion of the process. It can also be defined as the time interval between two consecutive finished products produced by a

machine or an entire production line. Cycle Time is an important indicator in production management because it helps evaluate process performance, identify bottlenecks, and find opportunities for improvement.

The formula for calculating Cycle Time is:

$$Cycle\ Time\ = \frac{Total\ Processing\ Time}{Number\ of\ Finished\ Products}$$

2.2.3. Lead Time

Lead Time is the total time required for a product or a batch of products to complete the entire process, from the beginning until it is finished and ready to be delivered to the customer or transferred to the next process. Lead Time includes both Value-Added Time (VA) and Non-Value-Added Time (NVA), such as waiting time, transportation time, inventory time, inspection time, and other activities that occur during the production process.

The formula for calculating Lead Time is:

Lead Time = Value - Added Time (VA) + Non-Value - Added Time (NVA)

2.2.4. Changeover Time

Changeover Time (CO) is the time required to prepare machines, equipment, or a production line when switching from producing one product to another, or from one process step to the next. This time includes activities such as setup, adjustment, inspection, and testing to ensure that the production process operates as required.

2.2.5. Available Production Time

Available Production Time (APT) is the total time available for production during a given period, such as a day, week, or month. It excludes break times, maintenance, and other non-productive activities.

2.2.6. Value – Added Time

Value-Added Time (VA) refers to the time spent on activities that directly increase the value of a product from the customer's perspective. These are activities that customers are willing to pay for because they transform raw materials or services into products that meet their needs and expectations.

2.2.7. Non – Value – Added Time

Non-Value-Added Time (NVA) refers to the time spent on activities that do not

add value to a product or service and are not necessary for the operation of the process. These activities increase time, cost, or complexity without contributing to the final product or service. Therefore, they should be minimized or eliminated whenever possible. Customers are not willing to pay for these activities because they do not provide any value to the final product or service.

2.3. Types of Waste in Manufacturing

Waste in manufacturing refers to activities or processes that do not create value for customers and do not contribute to increasing the value of a product or service. Waste reduces production efficiency and increases costs, which can negatively affect a company's profitability. According to lean manufacturing, there are seven types of waste:

1. Overproduction: Occurs when more is produced than the customer requires, or before the customer demands it.
2. Inventory: Refers to the use of more materials or information than necessary.
3. Time/Waiting: Refers to the time customers or employees have to wait to receive the product or service.
4. Transportation: Refers to the unnecessary movement of products from one location to another, or the transfer of products between employees.
5. Processing: Refers to unnecessary manual work that does not add value to the product.
6. Motion: efers to unnecessary physical or mental movement, often related to searching.
7. Defects: Occurs when a product fails to meet the required standards or has defects that affect the customer.

In the V120 production area, not all types of waste have the same level of impact. This study focuses on four types of waste that are directly related to the proposed improvement solutions: transportation waste, motion waste, waiting waste, and defects.

- Transportation waste occurs when raw materials are transported from the V120-1 warehouse to the nine injection molding machines in the V120-2 area. This activity is repeated many times a day, increasing the total travel distance and non-value-added time.
- Motion waste occurs in the BODY COVER 6Q4908 process, where operators have to remove the gate, arrange products into trays, transfer semi-finished

products, place parts into the drilling fixture, and perform repeated inspections.

- Waiting waste may occur when injection molding machines are not supplied with raw materials on time or when semi-finished products have to wait until a batch is completed before being transferred to the drilling area.
- Defects are related to problems such as burrs, scratches, film tearing, or position deviations caused by the drilling process.

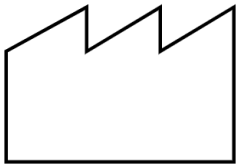
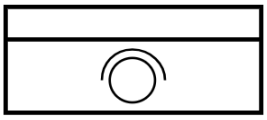
2.4. Value Stream Mapping

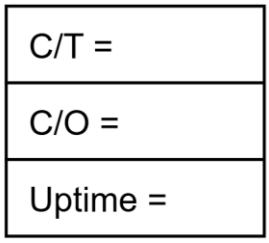
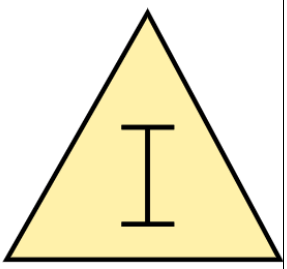
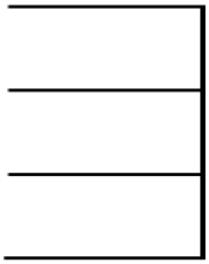
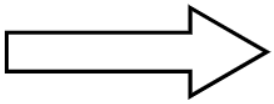
Value Stream Mapping (VSM) is a visual tool used to describe both the material flow and the information flow in a production process. VSM helps researchers understand the entire sequence of activities, from raw materials to finished products, rather than examining each process separately. Its main advantage is the ability to present value-added time, non-value-added time, inventory, information flow, and bottlenecks within a single map.

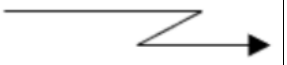
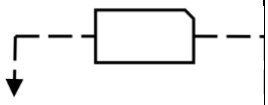
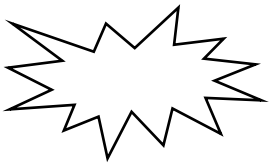
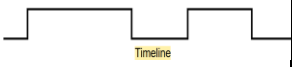
2.4.1. Value Stream Mapping Tools

The tools used to construst the value stream mapping are presented in table below.

Table 2.1. Value stream mapping tools

Type	Symbol	Name	Meaning
Process		Customer/Supplier	The symbol representing the supplier is placed at the top left corner of the diagram. Conversely, the symbol representing the customer is placed on the right.
		Specialized Process Flow	This symbol represents the fixed and continuous flow of internal materials through a department, process, activity, machine, and workers.

Type	Symbol	Name	Meaning
		Data Cell	These data cells are used to store information about other processes, serving the purpose of recordkeeping or analysis.
Material		Inventory	This symbol represents inventory that is being moved between two processes or stored for future use.
		Internal Transportation	The symbol of this tool represents the force that pushes materials from one process to another.
		Inventory Rack	This symbol represents a stock point where end customers can pick up the inventory they need as it is replenished by the supplier.
		External Transportation	Transportation of raw materials from suppliers or delivery of products to customers.
Information		Information Box	The symbol of this tool represents supplementary information describing the content written in the value stream mapping.
		Information Flow	Represents the manual flow of information through paperwork or direct

Type	Symbol	Name	Meaning
			communication.
		Electronic Information Flow	Represents the flow of information through networks or electronic devices.
		Kanban Production	Indicates the required production level to supply the subsequent stages.
		Kaizen	Analyze weaknesses and opportunities for improvement.
		Timeline	Represents waiting time and processing time. This can be used to calculate lead time and Cycle time.

2.4.2. Steps to Create a Value Stream Mapping

The VSM development process in this study consists of the following steps:

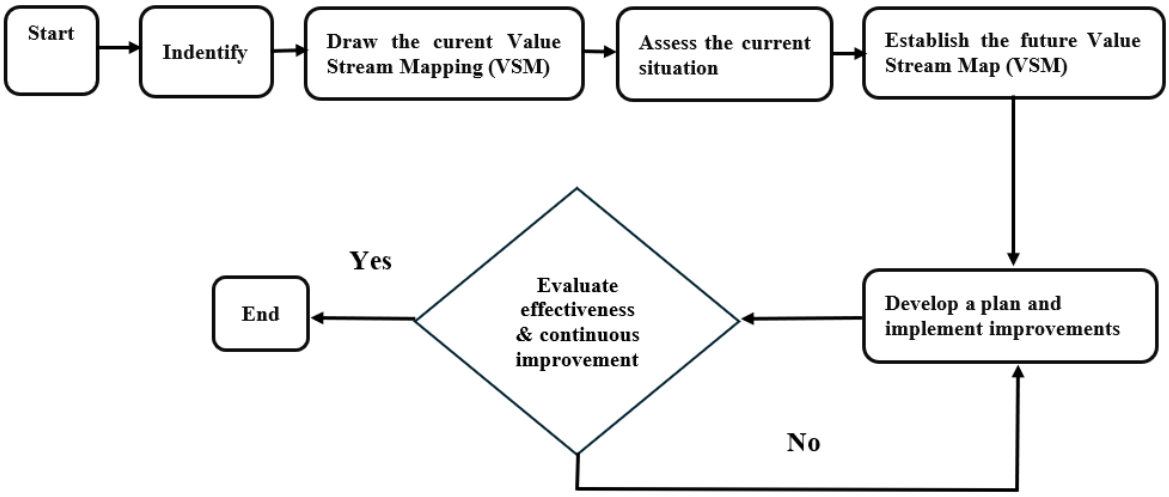


Figure 2.1. Steps to Create a Value Stream Mapping

Step 1: Identify the Product Family

The first step is to identify the product family or production line to be analyzed. Products with similar processing steps and production flows are grouped together to define the scope of the value stream mapping study.

Step 2: Draw the Current Value Stream Map

In this step, the current production process is mapped by collecting data on material flow and information flow. Important data such as Cycle Time (CT), Changeover Time (CO), inventory levels, and lead time are recorded to represent the current state of the production system.

Step 3: Assess the Current Situation

After completing the current VSM, the production system is evaluated to identify waste, bottlenecks, and non-value-added activities. This analysis helps determine areas that require improvement.

Step 4: Establish the Future Value Stream Map

Based on the problems identified in the current state, a future VSM is developed. The future map illustrates an improved production flow with reduced waste, shorter lead time, and better synchronization between processes.

Step 5: Develop an Improvement Plan and Implement Improvements

Improvement actions are proposed and implemented according to the future VSM. These actions may include layout redesign, process standardization, reduction of transportation and waiting time, or the application of Lean tools to improve production efficiency.

Step 6: Evaluate Effectiveness and Continuous Improvement

After implementation, the effectiveness of the improvements is evaluated by comparing key performance indicators before and after improvement, such as Lead Time, Cycle Time, productivity, and defect rate. If the results meet the expected objectives, the process can be standardized. Otherwise, additional improvements are developed and implemented continuously.

Step 7: End

The VSM improvement cycle is completed when the improvement objectives are achieved. However, continuous improvement remains an important principle of Lean Manufacturing to maintain and further enhance production performance.

2.4.3. Suitability of VSM for This Study

VSM is suitable for this study because both research problems are related to flow within the production system. The first problem is that the material flow from V120-1 to V120-2 is not optimized, resulting in long transportation distances. The second problem is that the flow of the BODY COVER 6Q4908 product after the injection molding process is interrupted because the gate must be trimmed, the products must be collected into trays and then transported to the drilling area. If only individual time measurements are used, these wastes may be considered normal operations. However, when they are represented on a value stream map (VSM), transportation and waiting times are clearly separated from value-added time. This allows the need for improvement to be demonstrated more clearly, both visually and quantitatively.

2.5. Fishbone Diagram

The Fishbone Diagram, also known as the cause-and-effect diagram, is a quality analysis tool used to identify and organize the possible causes of a problem in a production process. This diagram is called a "fishbone" because its structure resembles the skeleton of a fish, where the "head" represents the problem to be analyzed, and the "main bones" represent the major groups of causes leading to that problem.

In manufacturing, the Fishbone Diagram is commonly used to analyze the root causes of problems such as quality defects, long production time, low productivity, waste generation, unnecessary motions, or inefficient material flow. This tool helps improvement teams understand problems systematically, avoid subjective judgments, and support the selection of appropriate improvement solutions.

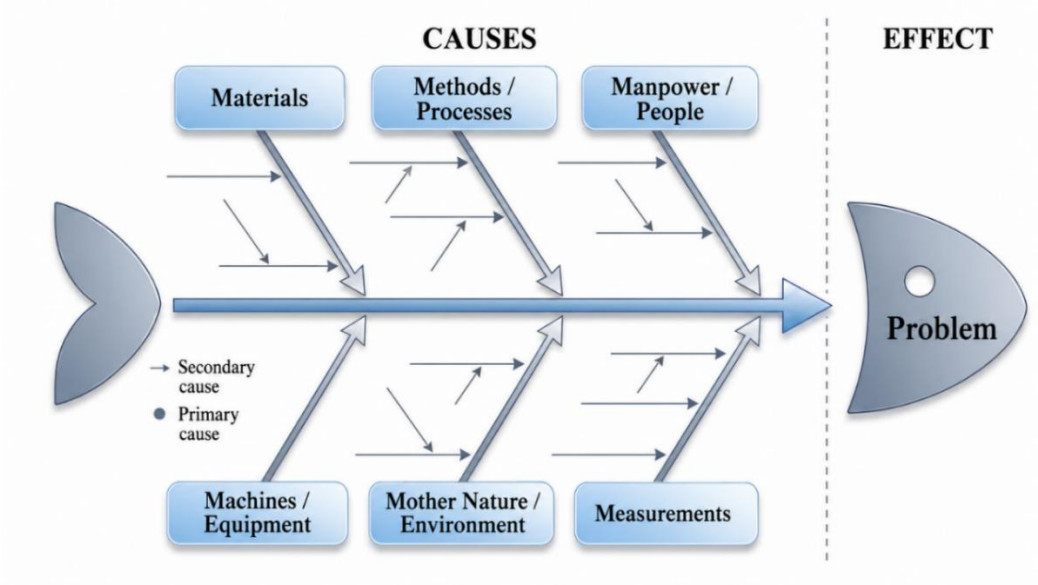


Figure 2.2. Illusrate the Fishbone Diagram

In the Fishbone Diagram, the fish head on the right side represents the problem to be analyzed, while the spine and branches represent the groups of causes that may lead to the problem. The causes are commonly classified according to the 6M model, including Materials, Methods/Processes, Manpower/People, Machines/Equipment, Mother Nature/Environment, and Measurements. Each main cause can be further divided into more specific causes to identify the root cause of the problem. With this systematic approach, the fishbone diagram helps improvement teams identify all relevant factors, avoid subjective judgments, and support the selection of appropriate improvement solutions. In this study, the fishbone diagram is used to analyze the causes of problems occurring in the V120 area, providing a basis for proposing and implementing improvement solutions to enhance production efficiency.

2.6. ECRS Method

ECRS is a process improvement method that consists of four principles: Eliminate, Combine, Rearrange, and Simplify. This method is widely used in manufacturing improvement to identify and eliminate non-value-added activities, reduce cycle time, minimize waste, and improve production flow efficiency. A key characteristic of ECRS is the evaluation of each operation or process step through four basic questions: Can it be eliminated? Can it be combined with another activity? Can it be rearranged into a more effective sequence? Can it be simplified? Through

this evaluation process, organizations can develop improvement solutions with relatively low implementation costs while achieving significant operational benefits.

- Eliminate: Remove unnecessary operations, activities, or processes that do not add value.
- Combine: Combine activities or processes that can be performed together to reduce the number of steps.
- Rearrange: Change the sequence of operations, equipment locations, or layout to reduce movement and create a smoother flow.
- Simplify: Simplify work methods, tools, or procedures to reduce processing time and worker fatigue.

ECRS can be applied to various manufacturing activities, including material supply, internal transportation, processing operations, quality inspection, and facility layout improvement. The application of ECRS helps reduce non-value-added activities, improve production flow, and support the effective implementation of Lean Manufacturing.

In this study, the ECRS method is used as a framework to analyze non-value-added activities in material supply and product processing operations. Based on this analysis, improvement solutions are proposed to reduce transportation, motion, and waiting time within the production system.

2.7. ABC Classification in Material Management

ABC Classification is an inventory management method used to classify materials according to their importance or usage level in production. This method is based on the Pareto principle, which states that a small number of materials usually account for a large proportion of total consumption, material issuance, or usage frequency.

In this study, the objective is to reduce the material supply time and transportation distance in the V120-2 area. Therefore, the ABC classification criteria are determined based on usage frequency, the number of material supply times per day, and material consumption per shift or per day.

According to the ABC method, materials are divided into three groups based on their usage level and importance in production. Group A includes materials with high usage frequency and a large proportion of total consumption. Group B includes

materials with a medium level of usage, while Group C consists of materials with low usage frequency and low consumption.

2.7.1. ABC Classification Formula

The usage ratio of each material can be calculated as follows:

$$Usage\ Ratio\ of\ Material\ i\ = (\frac{Usage\ of\ Material\ i}{Total\ Usage\ of\ All\ Materials})\ x\ 100\%$$

After calculating the usage ratio of each material, the materials are arranged in descending order according to their usage level. Then, the cumulative percentage is calculated to classify materials into three groups:

- Group A: Materials with the highest usage ratio, usually accounting for about 70–80% of the total material consumption. These materials should be given priority for storage near the production area and should be monitored frequently.
- Group B: Materials with a medium usage level, usually accounting for the next 15–20% of total consumption. These materials should be controlled periodically and can be stored in intermediate locations.
- Group C: Materials with a low usage level and the remaining small proportion of total consumption. These materials can be stored in the main warehouse or arranged flexibly to avoid occupying unnecessary space.

2.7.2. Importance of ABC Classification for the Material Staging Area

ABC analysis is an effective tool for inventory management and material storage planning. The classification results help companies identify materials with high usage levels and prioritize their control and placement near production areas. In contrast, materials with lower usage levels can be stored in less accessible locations to optimize storage space.

The application of ABC analysis helps improve material management efficiency, reduce the time required for material searching and replenishment, and support better material flow within the production system. In addition, this method provides an important basis for designing warehouse layouts and material staging areas that match actual production requirements.

2.8. Production Layout

Production layout refers to the proper arrangement of machines, material storage

areas, walkways, and workstations to ensure a continuous, efficient, and safe flow of materials. In Lean Manufacturing, a well-designed layout helps reduce transportation waste, unnecessary motion, waiting time, and work-in-process inventory, thereby shortening Lead Time and improving production efficiency. Therefore, facility layout is considered one of the key tools for improving material flow and supporting the effective implementation of Lean Manufacturing.

2.8.1. Objectives of Production Layout

The main objective of Production Layout is to create a production system with an efficient Material Flow, minimize Non-Value-Added activities, and improve the utilization of resources. A good Production Layout should achieve the following objectives:

First, reduce material transportation distance: Raw materials, semi-finished products, and finished products should be located close to the point of use in order to reduce transportation time, minimize transportation waste, and shorten Lead Time. Second, reduce the number of movements and material handling activities: A well-organized material storage area enables one material supply trip to serve multiple machines or different types of materials, thereby reducing the number of trips required each day. Third, create a continuous material flow: The layout should be designed so that materials move in a clear and logical direction, avoiding unnecessary detours, intersections, or overlapping transportation routes. Fourth, utilize factory space effectively: The material buffer area should provide sufficient storage capacity without obstructing walkways, work areas, safety zones, or existing production activities. Fifth, ensure safety and operational convenience: The new layout should provide enough space for operators, carts, pallets, and machines to operate efficiently and safely. In addition, it should not block emergency exits or create safety hazards.

2.8.2. Lean Principles of Production Layout

In Lean Manufacturing, production layout should focus on reducing non-value-added activities, especially transportation, waiting, unnecessary motion, and work-in-process inventory. The main principles are as follows:

First, arrange the layout according to the production flow: Production areas should be organized following the sequence of material usage, from the raw material

warehouse to production machines, processing operations, and finished products. This arrangement allows materials to move in a logical flow, reduces unnecessary transportation, shortens waiting time, and minimizes work-in-process inventory. Second, place materials close to the point of use: Frequently used materials should be stored near the production area to minimize material handling and replenishment time. This principle is commonly used in conjunction with ABC analysis to prioritize material placement based on consumption frequency and inventory importance. Third, reduce intersections in material flow: Material transportation routes should be clear, short, and have minimal interference with the movement of operators, carts, or finished products. This helps improve operational safety, makes the process easier to manage, and avoids congestion in the production area. Fourth, establish fixed and easily identifiable storage locations: Materials should be arranged by area, material code, or usage group and should have clear labels or identification marks. This arrangement helps operators find and retrieve materials easily, simplifies inventory control, and reduces the risk of supplying incorrect materials. Fifth, maintain flexibility while ensuring effective control: The material staging area at V120-2 should have an appropriate size. It should not be too large, which would occupy unnecessary production space, nor too small, which would require frequent replenishment. The inventory level should be determined based on usage frequency, material consumption per shift or per day, and the actual production space available.

2.8.3. Selection Criteria and Application of the Material Staging Area

The selection of a material staging area should be based on several factors to ensure efficient material flow and improve operational performance. The staging area should be located close to the point of use, have sufficient storage capacity, and allow convenient replenishment from the main warehouse. In addition, the area should not interfere with production activities, worker movement, or workplace safety requirements. To improve efficiency, materials should be selected based on their usage frequency. Frequently used materials should be stored close to the production area, while materials with lower usage frequency can remain in the main warehouse. This approach helps reduce material handling activities, improve material availability, and support a continuous production flow.

2.9. Post-Molding Processing Technology: Drilling and Gate Stamping

In plastic injection molding production, excess plastic material often remains at the gate location after the molding process and must be removed before the product proceeds to the next operation. The gate processing operation directly affects the product's appearance quality, dimensional accuracy, assembly performance, and overall product quality. In industrial practice, various gate processing methods are available, among which drilling and stamping are two commonly used techniques. Each method has its own technical characteristics, advantages, and limitations. Therefore, understanding these methods provides an important basis for evaluating and selecting appropriate improvement solutions in injection molding production.

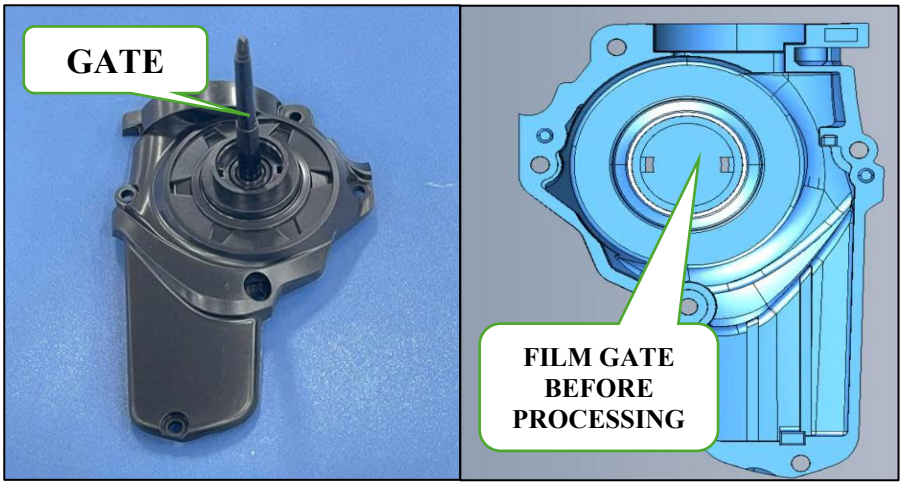


Figure 2.3. Gate & Film Gate Locations on BODY COVER 6Q4908

2.9.1. Principle of Drilling for Gate Processing

Drilling for gate processing is a method that uses a drill bit to remove excess plastic remaining at the gate area after the injection molding process. After molding, the product is placed in a fixture to keep it in the correct position. The drill bit is then used to remove the excess plastic so that the product meets the required shape, size, and appearance.

The basic process includes taking the molded product, placing it in the fixture, positioning the product, drilling the gate area, removing the product, checking its appearance, and sending it to the next process. In some cases, the operator first breaks the gate by hand and then drills or mills the remaining film gate.

The advantages of the drilling method are its simple operation, common equipment, and suitability for many types of products. However, this method also has some limitations. The processing quality depends on the operator's skill and product positioning. In addition, the drill bit may wear over time, which can cause defects such as burrs, film tearing, or surface scratches that affect product appearance.

2.9.2. Principle of Stamping for Gate Processing

Stamping for gate processing is a method that uses pressing force through a punch and die set to cut or remove the excess plastic at the gate location after the injection molding process. The molded product is placed in a positioning fixture, and the punch then presses on the gate area to remove the excess material according to a predefined shape and size.

The basic stamping procedure includes the following steps: taking the molded product, placing it into the stamping fixture, positioning it correctly, performing the stamping operation, removing the product, and inspecting its appearance. Compared with drilling or milling methods, stamping can reduce processing time because it does not require rotating cutting tools and involves fewer additional processing steps.

The main advantages of the stamping method are its fast operation, stable performance, and lower dependence on operator skills. If the punch, die, and fixture are designed accurately, the cutting position will be more consistent, helping to reduce burrs, dimensional deviations, and appearance defects. In addition, the stamping operation can be located close to the injection molding area, thereby reducing the transportation of semi-finished products to the drilling area and improving the continuity of production flow.

However, the stamping method also requires appropriate technical conditions. The punch and die must have accurate dimensions, the fixture must hold the product securely, and the stamping force must be sufficient to process the gate without causing cracks, dents, or product deformation. Therefore, before full-scale implementation, trial runs and quality inspections should be conducted to ensure that the product meets the required technical and appearance standards.

2.9.3. Comparison Between Drilling and Stamping for Gate Processing

Table 2.2. Comparison Between Drilling and Stamping for Gate Processing

Criteria	Drilling for Gate Processing	Stamping for Gate Processing
Working Principle	Uses a rotating drill bit to remove the gate.	Uses the pressing force of a punch and die to remove the gate.
Operation	Multiple steps: place the product in a fixture, drill/mill, remove the product, and inspect.	Fewer steps: place the product, stamp, remove the product, and inspect.
Processing Time	Longer and may involve additional waiting and transportation time.	Faster and helps shorten the processing time.
Quality	Easily affected by tool wear and operator skills.	More stable if the punch, die, and fixture are accurately designed.
Risk of Defects	May cause burrs, scratches, or position deviation.	Reduces burrs and dimensional deviations, but stamping force must be controlled.
Production Layout	Usually requires a separate drilling area, resulting in additional transportation.	Can be located close to the post-molding area, reducing transportation distance.
Suitability	Suitable for low production volume or products with frequent design changes.	Suitable for stable production volume and products with gates that can be processed by stamping.
Impact on Lean/VSM	Increases motion, transportation, and non-value-added (NVA) time.	Reduces motion, decreases NVA time, and shortens lead time.

2.9.4. Conditions for Changing from Drilling to Stamping

Changing the gate processing method from drilling to stamping involves not only a change in processing tools but also affects product quality, operating procedures, equipment capacity, and production layout. Therefore, the following conditions should be evaluated before implementing the new method:

- The gate and film gate should have appropriate geometry, length, and thickness so that they can be processed by stamping without causing cracks, dents, or product deformation.
- The punch, die, and stamping fixture should be designed accurately to ensure correct product positioning and prevent surface scratches.
- The stamping force should be sufficient to process the gate but should not be excessive, as this may damage the product or affect the assembly area.
- The product after stamping should meet the required standards for appearance, burr level, dimensions, and assembly performance.
- The stamping machine capacity and operators should be able to meet the actual production demand, preventing the stamping process from becoming a new bottleneck.
- Standard operating procedures, inspection guidelines, and punch/die maintenance plans should be established to ensure stable performance during mass production.

Therefore, before replacing the drilling method with the stamping method, it is necessary to evaluate both the technical feasibility and the ability to meet production requirements. The successful application of the stamping method depends on several factors, including product geometry, reliable tooling design, stable process operation, and compliance with quality requirements. These conditions provide the basis for assessing the feasibility of the proposed improvement solution.

Chapter 3: Current Situation Analysis at the V120 Department

3.1. Description of the Current Production System at the V120 Department

The V120 department is an injection molding area belonging to the REEL production division, responsible for the injection molding process and several post-molding finishing operations. According to the current production data, the production area covers approximately 3.000 m² and is divided into two sections: V120-1 and V120-2. The total number of injection molding machines in the V120 department is 44, including 35 machines in V120-1 and 9 machines in V120-2.

The overall production flow of the department consists of raw material storage, material supply, injection molding, post-molding processing, and transfer to the next process. The information flow starts from the production plan, which determines the material type, required quantity, material supply timing, and destination machine. Based on this information, the material flow is carried out from the raw material warehouse to the injection molding machines and then continues through the post-molding processing stage.

In Chapter 3, this study focuses on analyzing two flows that directly affect the operational efficiency of the V120 department: the material supply flow from the V120-1 warehouse area to the nine injection molding machines in V120-2 and the post-molding processing method of the BODY COVER 6Q4908 product. These two areas contain a significant amount of non-value-added time, particularly transportation, repetitive operations, waiting, and quality-related risks.

3.2. Data Collection and Analysis Methods

To avoid subjective evaluation of the current situation, data were collected through direct observation at the production site, time measurement sheets, distance measurement records, value stream mapping (VSM), material usage data, and industrial engineering (IE) reports for the BODY COVER 6Q4908 process. The collected data were then standardized into different groups of indicators for analyzing the value stream and identifying improvement opportunities.

Data Category	Collected Data	Purpose of Analysis
Material Supply Data	One-way transportation distance, travel time, material picking time, material loading time, return time, and number of supply trips per day.	Calculate the total transportation distance, total material supply time, and transportation waste.
Material Data	List of materials used in V120, materials used for V120-2, total material consumption, and daily material usage.	Perform ABC classification and identify materials with high usage frequency.
BODY COVER 6Q4908 Processing Data	Current drilling process, operation time for each step, transportation time to the drilling area, and defect risks.	Analyze wastes related to motion, transportation, waiting, and defects in the post-molding process.
VSM Data	Cycle Time (CT), Value-Added Time (VA), Non-Value-Added Time (NVA), number of operators, Available Production Time (APT), and Changeover Time (CO).	Develop the current-state Value Stream Map and identify the main bottlenecks in the production flow.

During the analysis process, Value-Added Time (VA) is defined as the time directly spent transforming the product or performing activities that are necessary for creating the product. Non-Value-Added Time (NVA) refers to the time spent on transportation, waiting, movement, or other activities that do not directly add value to the product. The Lead Time of the process is calculated using the following equation: Lead Time = VA + NVA.

3.3. Analysis of the Current Layout and Material Supply Activities at V120

3.3.1. Current Layout

The total area of the injection molding department is approximately 3.000 m² (40 m in width and 75 m in length), consisting of two production areas: V120-1 and V120-2. V120-1 is equipped with 35 injection molding machines, while V120-2 has 9 injection molding machines. Currently, raw materials are mainly stored in the

V120-1 warehouse and must be transported to V120-2 to supply the nine injection molding machines. This material supply process involves a long transportation distance and requires a considerable amount of time, resulting in transportation waste and non-value-added activities.

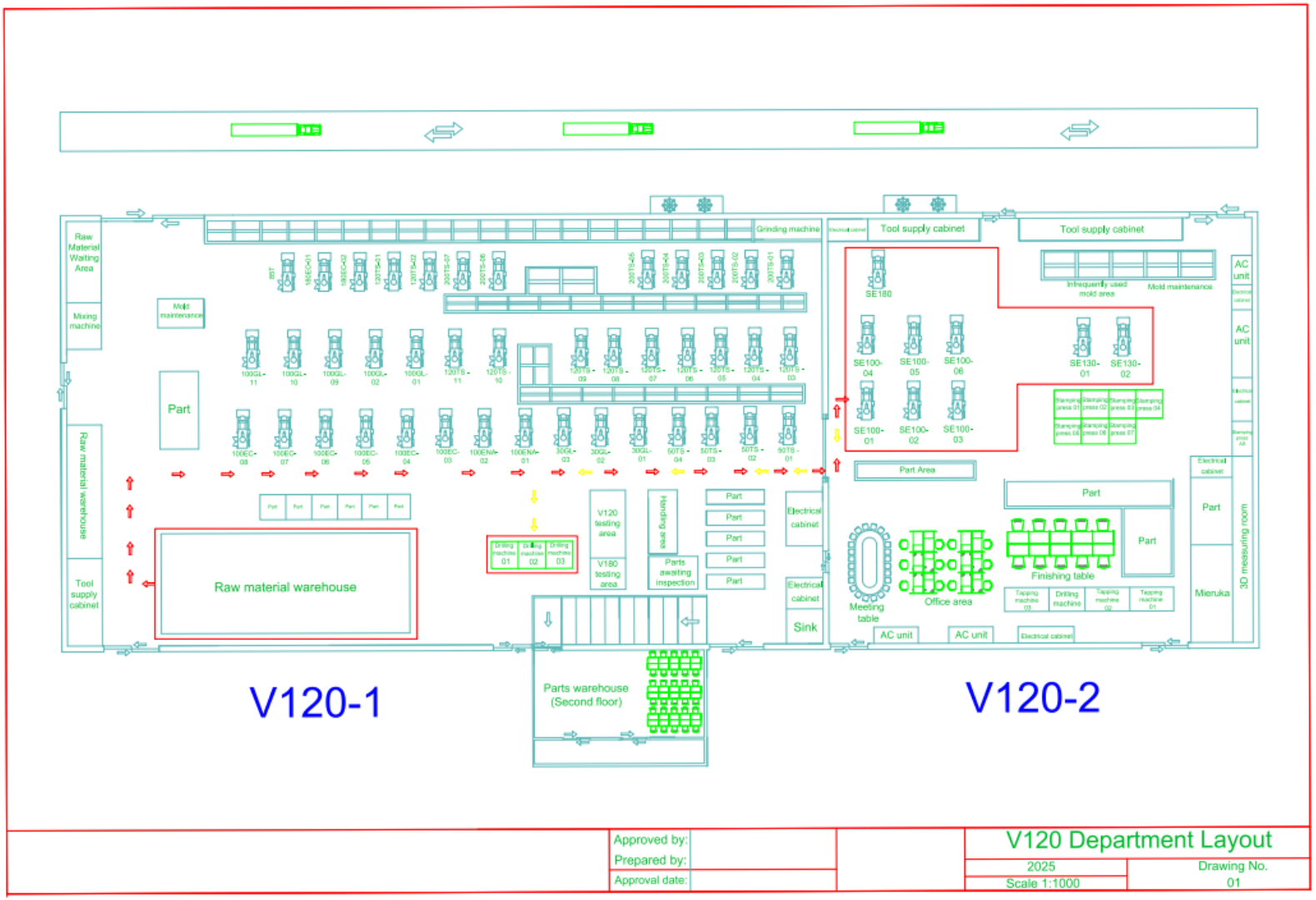


Figure 3.1. Current Layout of the V120 Department

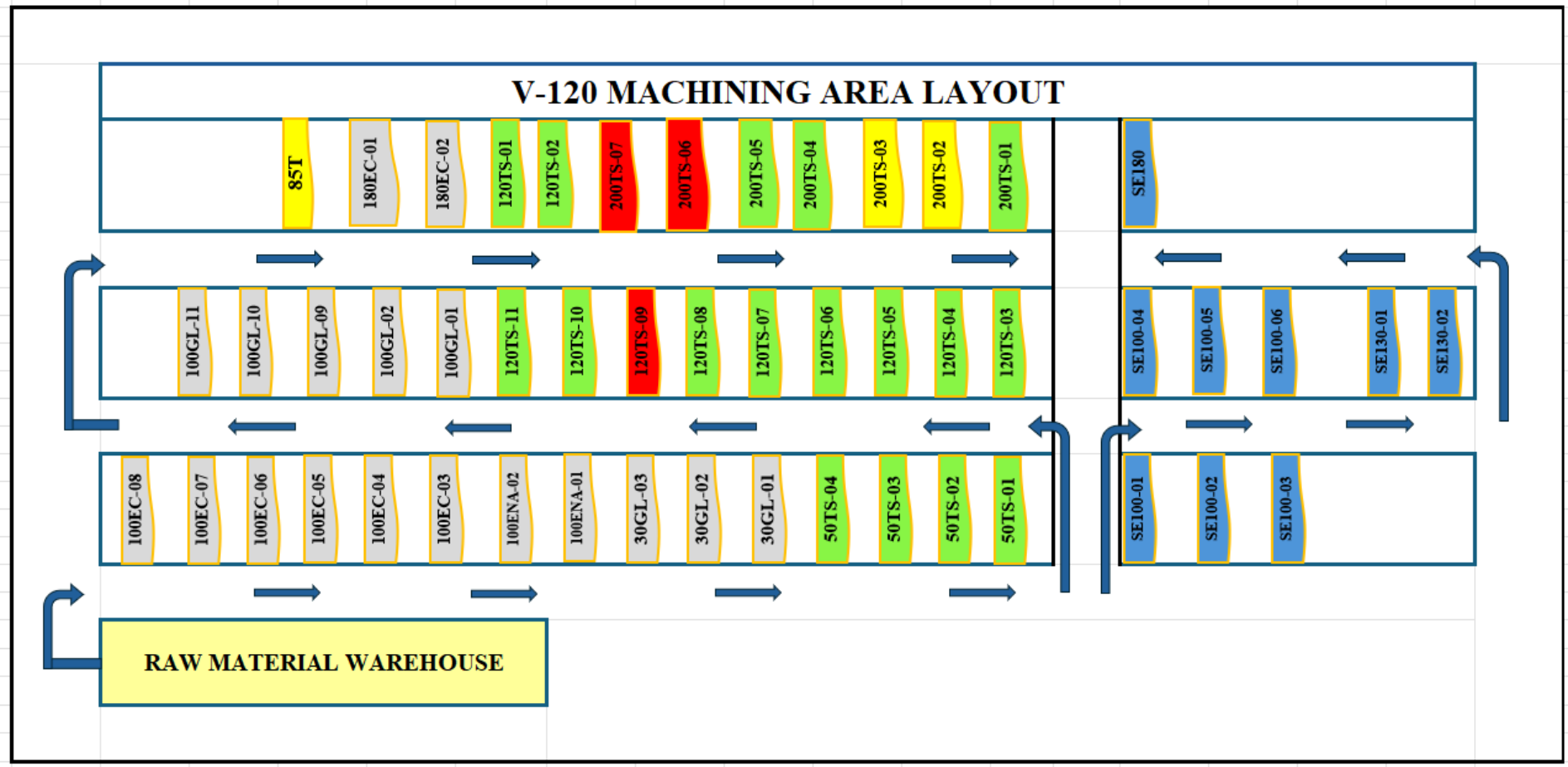


Figure 3.2. V120 Machine Area Layout

3.3.2. Measurement of Material Supply Time and Transportation Distance

Table 3.1. Measurement of Material Supply Time and Transportation Distance

NO.	Current material supply route	Receiving machine	One-way distance (m)	Two- way distance (m)	Moving time (s)	Resin picking time (s)	Material loading time (s)	Return time (s)	Total time per cycle (s)	Feeding frequeny per day	Total distance per day (m)	Total time per day (s)
1	Warehouse V120-1 → V120-2	SE100-06	72,4	144,8	108,6	10	25	72,4	216	3	434,4	648
2	Warehouse V120-1 → V120-2	SE130-01	80,5	161	120,75	10	25	80,5	236,25	3	483	708,75
3	Warehouse V120-1 → V120-2	SE130-02	85,2	170,4	127,8	10	25	85,2	248	3	511,2	744
4	Warehouse V120-1 → V120-2	SE180	92,3	184,6	138,45	10	25	92,3	265,75	3	553,8	797,25
5	Warehouse V120-1 → V120-2	SE100-01	64,5	129	96,75	10	25	64,5	196,25	3	387	588,75
6	Warehouse V120-1 → V120-2	SE100-02	69	138	103,5	10	25	69	207,5	3	414	622,5
7	Warehouse V120-1 → V120-2	SE100-03	73	146	109,5	10	25	73	217,5	3	438	652,5
8	Warehouse V120-1 → V120-2	SE100-04	65	130	97,5	10	25	65	197,5	3	390	592,5
9	Warehouse V120-1 → V120-2	SE100-05	68,5	137	102,75	10	25	68,5	206,25	3	411	618,75

The one-way transportation distance from the V120-1 warehouse to each machine in V120-2 ranges from 64,5 m to 92,3 m. On average, each machine is supplied with materials three times per day, resulting in a total of 27 supply trips per day for all nine machines. Since the transportation route is repeated many times throughout the day, transportation waste is generated not only in each individual trip but also accumulates into a significant total transportation distance and time. The total material transportation distance in the current state is 4.022 m/day, equivalent to approximately 4,02 km/day. The total material supply time is 5.973 seconds/day, equivalent to 99,55 minutes/day. With 27 supply trips per day, the average time required for each material supply cycle is approximately 221,2 seconds. This is a considerable amount of time for an activity that does not directly add value to the product. Among the nine machines receiving materials, machine SE180 has the longest one-way transportation distance at 92,3 m and requires a total material supply time of 797,25 seconds per day. This indicates that the problem is not limited to a single machine but is related to the overall material supply layout of the V120-2 area.

❖ **Observations**

The current material supply route starts from the centralized warehouse in V120-1 and extends to V120-2, resulting in long transportation distances and repeated supply trips throughout the day. Transportation activities account for a significant portion of each material supply cycle, even though they do not directly add value to the product. In addition, there is currently no Material Staging Area near the V120-2 machine group for frequently used materials. As a result, all materials must be supplied from the main warehouse, increasing transportation time and dependency on V120-1. The collected distance and time data indicate that the current layout should be redesigned by locating frequently used materials closer to the point of use. However, the selection of materials for the Material Staging Area should be based on ABC analysis to avoid excessive or unnecessary inventory storage.

❖ **Fishbone Diagram of the causes of transportation waste in the material supply process at V120-2.**

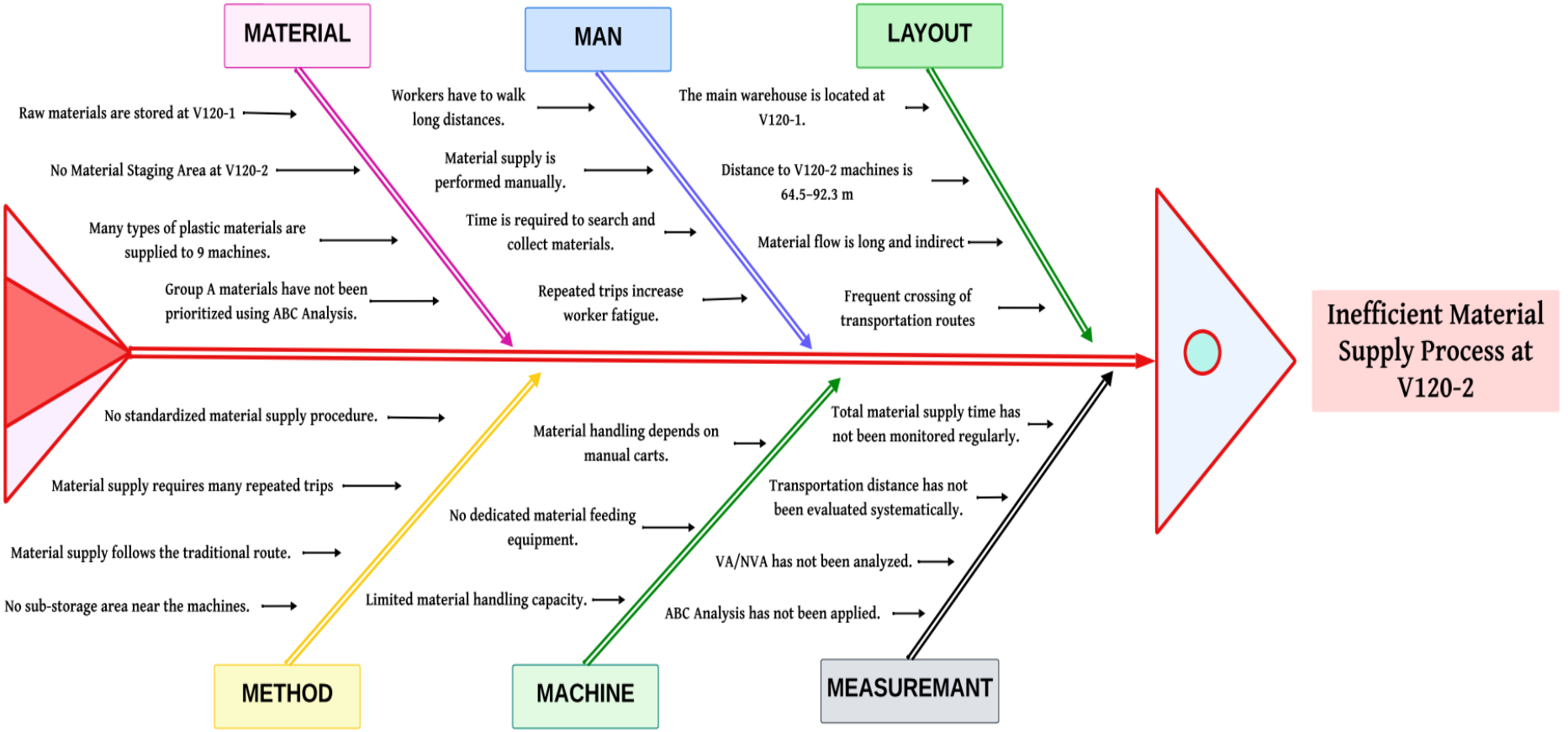


Figure 3.3. Fishbone Diagram of Transportation Waste Causes in the Material Supply Process at V120-2.

3.4. Analysis of Material Usage at V120-2

3.4.1. List of Materials Used at V120-2

According to the material data, the V120 Department uses approximately 15 types of plastic resins and color masterbatches, as shown in the table below.

Table 3.2. List of Materials Used in the V120 Area

No.	Material
1	ABS-P
2	ABS-S
3	DSP-40
4	DSP-46
5	DSP-53
6	LTU
7	MB-ABS-P535
8	RUN-GR1
9	MB-PP-M-P535 (ROYALBLAK 9002P)
10	PA-6
11	POM-M (500P BK 602)
12	POM-S (M90-44)
13	PP-M (J106MG)
14	DSP-37
15	SEBS (SJ7400BK)

However, not all of the raw materials listed above are directly used in the V120-2 production area. Since the scope of this study focuses on the nine injection molding machines in V120-2, it is necessary to further filter the data to identify the materials that are actually consumed in this area. Identifying the correct group of materials used in V120-2 provides an important basis for analyzing material consumption, material feeding frequency, and evaluating the possibility of locating a material staging area closer to the injection molding machines.

3.4.2. Analysis of Materials Used in the V120-2 Area

To evaluate the material requirements for production in the V120-2 area, production planning data and material supply records were collected and analyzed. The collected data include product codes, production quantities, types of raw materials used, production schedules, and the corresponding injection molding machines. Based on these data, the frequency of use and consumption level of each material were analyzed to identify frequently used materials, which serve as the basis for establishing a material storage area near the point of use and optimizing the material supply process in V120-2.

	PARTS	MOUL	PARTS NA	QTY PAF	STARTD	DELIVE	COLO	MATERIA	DATE	MACHINE
2	BQ5188ABE	BQ5188	BODY(BLANK)	682	27/02/25	03/03/25	P00N	RUN-GR1	3/1/2025	SE100/01
3	BQ5188ABE	BQ5188	BODY(BLANK)	455	03/03/25	06/03/25	P00N	RUN-GR1	3/1/2025	SE100/01
4	BQ5188ABE	BQ5188	BODY(BLANK)	114	04/03/25	07/03/25	P00N	RUN-GR1	3/1/2025	SE100/01
5	BQ5188ABE	BQ5188	BODY(BLANK)	114	04/03/25	07/03/25	P00N	RUN-GR1	3/1/2025	SE100/01
6	BQ5188ABE	BQ5188	BODY(BLANK)	228	04/03/25	07/03/25	P00N	RUN-GR1	3/1/2025	SE100/01
7	BQ5188ABE	BQ5188	BODY(BLANK)	114	04/03/25	07/03/25	P00N	RUN-GR1	3/1/2025	SE100/01
8	BQ5188ABE	BQ5188	BODY(BLANK)	341	07/03/25	12/03/25	P00N	RUN-GR1	3/3/2025	SE100/01
9	BQ5188ABE	BQ5188	BODY(BLANK)	682	13/03/25	17/03/25	P00N	RUN-GR1	3/3/2025	SE100/01
10	BQ5188ABE	BQ5188	BODY(BLANK)	2101	24/03/25	29/03/25	P00N	RUN-GR1	3/5/2025	SE100/01
11	BQ5188ABE	BQ5188	BODY(BLANK)	58	26/03/25	29/03/25	P00N	RUN-GR1	3/5/2025	SE100/01
12	BQ5188ABE	BQ5188	BODY(BLANK)	114	28/03/25	01/04/25	P00N	RUN-GR1	3/5/2025	SE100/01
13	BQ5188ABE	BQ5188	BODY(BLANK)	114	28/03/25	01/04/25	P00N	RUN-GR1	3/5/2025	SE100/01
14	BQ5188ABE	BQ5188	BODY(BLANK)	455	28/03/25	01/04/25	P00N	RUN-GR1	3/5/2025	SE100/01
15	BQ5188ABE	BQ5188	BODY(BLANK)	682	01/04/25	04/04/25	P00N	RUN-GR1	3/6/2025	SE100/01
16	BQ5188ABE	BQ5188	BODY(BLANK)	795	08/04/25	11/04/25	P00N	RUN-GR1	3/6/2025	SE100/01
17	BQ5188ABE	BQ5188	BODY(BLANK)	58	08/04/25	11/04/25	P00N	RUN-GR1	3/6/2025	SE100/01
18	BQ5188ABE	BQ5188	BODY(BLANK)	328	08/04/25	11/04/25	P00N	RUN-GR1	3/7/2025	SE100/01
19	BQ5188ABE	BQ5188	BODY(BLANK)	795	05/04/25	11/04/25	P00N	RUN-GR1	3/7/2025	SE100/01
20	BQ5188ABE	BQ5188	BODY(BLANK)	455	11/04/25	15/04/25	P00N	RUN-GR1	3/9/2025	SE100/01
21	BQ5188ABE	BQ5188	BODY(BLANK)	1704	10/04/25	15/04/25	P00N	RUN-GR1	3/10/2025	SE100/01
22	BQ5188ABE	BQ5188	BODY(BLANK)	341	14/04/25	17/04/25	P00N	RUN-GR1	3/10/2025	SE100/01
23	BQ5188ABE	BQ5188	BODY(BLANK)	277	14/04/25	17/04/25	P00N	RUN-GR1	3/11/2025	SE100/01
24	BQ5188ABE	BQ5188	BODY(BLANK)	58	22/04/25	25/04/25	P00N	RUN-GR1	3/11/2025	SE100/01
25	BQ5188ABE	BQ5188	BODY(BLANK)	58	22/04/25	25/04/25	P00N	RUN-GR1	3/11/2025	SE100/01
26	BQ5188ABE	BQ5188	BODY(BLANK)	58	22/04/25	25/04/25	P00N	RUN-GR1	3/11/2025	SE100/01
27	BQ5188ABE	BQ5188	BODY(BLANK)	909	24/04/25	28/04/25	P00N	RUN-GR1	3/11/2025	SE100/01
28	BQ5188ABE	BQ5188	BODY(BLANK)	909	24/04/25	28/04/25	P00N	RUN-GR1	3/12/2025	SE100/01
29	BQ5188ABE	BQ5188	BODY(BLANK)	328	25/04/25	29/04/25	P00N	RUN-GR1	3/12/2025	SE100/01
30	BQ5188ABE	BQ5188	BODY(BLANK)	114	06/05/25	09/05/25	P00N	RUN-GR1	3/12/2025	SE100/01
31	BQ8168ABC	BQ8168	ROTOR(BLANK)	1182	25/02/25	01/03/25	P00N	DSP-46	3/1/2025	SE100/02
32	BQ8168ABC	BQ8168	ROTOR(BLANK)	44	28/02/25	04/03/25	P00N	DSP-46	3/1/2025	SE100/02
33	BQ8168ABC	BQ8168	ROTOR(BLANK)	592	28/02/25	05/03/25	P00N	DSP-46	3/3/2025	SE100/02
34	BQ8771ABB	BQ8771	BODY(BLANK)	902	05/03/25	11/03/25	P583	DSP-53	3/9/2025	SE100/02
35	BQ8168ABC	BQ8168	ROTOR(BLANK)	887	07/03/25	12/03/25	P00N	DSP-46	3/3/2025	SE100/02

Figure 3.4. Raw Material Usage Data in the V120-2 Area

The survey results show that many product codes are produced repeatedly with high frequency on injection molding machines at area V120-2. For example, product BQ5188 is processed on machine SE100/01 using RUN-GR1 material across multiple production orders, with quantities ranging from several dozen to over 2.000

units per order. This indicates that the demand for raw materials in the V120-2 area occurs frequently and continuously. Based on this, the study proceeds to aggregate production output by each type of raw material and each injection molding machine in the V120-2 area.

Table 3.3. Summary of Material Usage Output by Machine in Area V120-2 (March, April, May 2025)

Sum of QTY PARTS	**Column Labels**									
Row Labels	**SE100/ 01**	**SE100/ 02**	**SE100/ 03**	**SE100/ 04**	**SE100/ 05**	**SE100/ 06**	**SE130/ 01**	**SE130 /02**	**SE 180**	**Grand Total**
ABS-P					36479					36479
DSP-46		7154	28188	15211	7761	16173			10952	85439
DSP-53		16218				1251			4131	21600
PP-M								56867		56867
RUN-GR1	13441					4895			1955	20291
S.E.B.S							56867			56867
Grand Total	**13441**	**23372**	**28188**	**15211**	**44240**	**22319**	**56867**	**56867**	**17038**	**277543**

Material output data by machine at V120-2 are presented in a column chart in Figure 3.4 to visualize the consumption level of each type of material on the injection molding machines during the survey period.

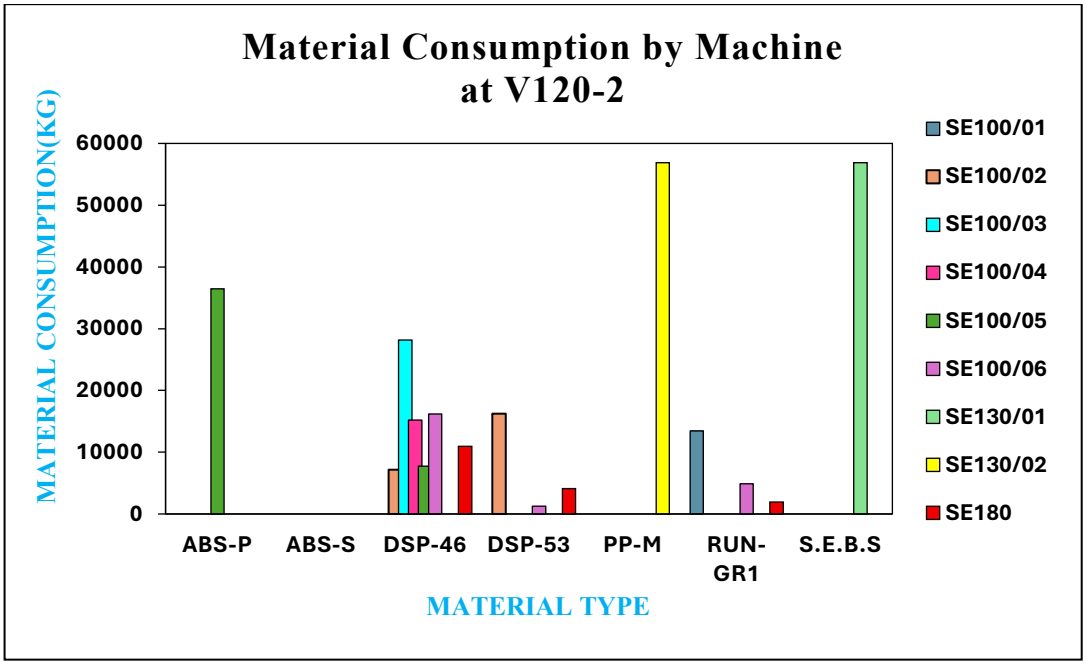


Figure 3.5. Material Output by Machine at V120-2 Area

Based on production data in the V120-2 area, it can be identified that the group of raw materials used in Workshop 2 consists of 7 main types: ABS-P, ABS-S, DSP-46, DSP-53, PP-M, RUN-GR1, and S.E.B.S. These materials are distributed across 9 injection molding machines, including SE100/01, SE100/02, SE100/03, SE100/04, SE100/05, SE100/06, SE130/01, SE130/02, and SE180. This serves as a basis for further analysis of material usage levels, conducting ABC classification, and proposing a layout plan for a material staging area at V120-2. The aim is to reduce transportation distance, material supply time, and waste in the production process.

3.5. Analysis of the Manufacturing Process of BODY COVER 6Q4908

3.5.1. Introduction of BODY COVER 6Q4908

BODY COVER 6Q4908 is a plastic component of the S331 model, used in the body assembly of Daiwa fishing reels. This part protects the internal components and contributes to the external appearance and overall aesthetics of the product. Since it is located in a visible position, BODY COVER 6Q4908 requires good surface quality, dimensional accuracy, and stable assembly performance. The product is manufactured in the V120 plastic molding department using an injection molding process on the SE100-03 injection molding machine. The material used is DSP-46 resin, which has good impact resistance, stable flexibility, and high surface quality. These properties make it suitable for components that require both durability and good appearance. After the injection molding process, excess material remains at the Film Gate area and must be removed before the product can proceed to the next process. Currently, this operation is carried out by a drilling process. The production flow includes material loading, injection molding, gate processing, visual inspection, and final handling. BODY COVER 6Q4908 was selected as the study product because it is produced regularly in the V120 department with a stable production volume and currently uses the drilling method for gate processing. Analyzing the current process and evaluating the possibility of changing the processing method will provide a basis for proposing improvement solutions to enhance production efficiency in the V120 department.

3.5.2. Current Manufacturing Process

Table 3.4. ECRS Analysis of the BODY COVER 6Q4908 Production Process

NO.	Process Stage	Operation Symbols				E	C	R	S	Problem
		Operation	Transportation	Inspection	Delay					
1	Take DSP-46 material and load it onto the cart	○	⇨	◇	▽	X				
2	Move to the required production machine	○	⇨	◇	▽	X				Long transportation time
3	Pour DSP-46 material into the container	○	⇨	◇	▽					
4	Close the container lid and start the Drying Hopper to transfer resin into the machine	○	⇨	◇	▽					
5	Record the daily resin-loading log	○	⇨	◇	▽					
6	Move back to the warehouse	○	⇨	◇	▽					Long transportation time
7	Automatic production machine	○	⇨	◇	▽					
8	Manually break the injection gate	○	⇨	◇	▽	X				Repetitive operations
9	Visual inspection	○	⇨	◇	▽	X				
10	Place into basket	○	⇨	◇	▽	X				
11	When the lot is complete, move to the drilling area	○	⇨	◇	▽	X				Long transportation time
12	Take the product and place it into the drilling jig	○	⇨	◇	▽			X		
13	Drilling process	○	⇨	◇	▽			X		
14	Unload product	○	⇨	◇	▽					
15	Visual inspection	○	⇨	◇	▽					
16	Place into basket	○	⇨	◇	▽					

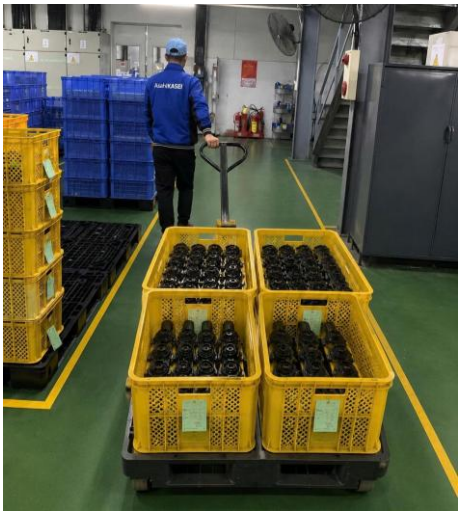
❖ Process Steps and Visual Illustrations of the Actual Production Process

Table 3.5. Process Steps and Visual Illustrations of the Actual Production Process.

NO.	Process Stage	Illustrative Images
1	Take DSP-46 material and load it onto the cart	
2	Move to the required production machine	
3	Pour DSP-46 material into the container	

4	Close the container lid and start the Drying Hopper to transfer resin into the machine	
5	Record the daily resin-loading log	
6	Move back to the warehouse	

7	Automatic production machine	
8	Manually break the injection gate	
9	Visual inspection	

10	Place into basket	
11	When the lot is complete, move to the drilling area	
12	Take the product and place it into the drilling jig	

13	Drilling process	
14	Unload product	
15	Visual inspection	

16	Place into basket	

The current manufacturing process of the BODY COVER 6Q4908 product consists of material supply, injection molding, and post-molding processing operations. The analysis results indicate that the process still includes several intermediate steps and generates a number of Non-Value-Added (NVA) activities. In particular, after the molding process, the product must undergo manual injection gate breaking, be collected into baskets, and then be transferred to the drilling area for further processing. This interrupts the production flow and increases the number of manual operations performed by workers.

In addition, transportation activities such as moving raw materials from the warehouse to the production machines, returning to the warehouse, and transporting semi-finished products to the drilling area do not directly add value to the product but still account for a significant portion of the overall process.

The ECRS analysis shows that several operations can be improved by eliminating unnecessary activities and rearranging the manufacturing process. This serves as the basis for proposing the conversion from the drilling method to Stamping for Gate Processing, with the aim of reducing manual operations, shortening transportation time, minimizing Non-Value-Added (NVA) time, and improving production efficiency in the V120 Department.

3.5.3. Current Drilling Process for Gate Processing

Currently, the Gate Processing operation for the BODY COVER 6Q4908 product is performed using a drilling method after the injection molding process. Although the drilling method is easy to implement and suitable for various types of products, the process still has several limitations. The machining quality at the Film Gate area depends largely on the condition of the drill bit, the accuracy of the fixture, and the

operator's handling skills. When the drill bit becomes worn or the product positioning is unstable, defects such as burrs, Film Gate tearing, surface scratches, or appearance deviations may occur. Therefore, it is necessary to investigate a more stable processing method to improve product quality and reduce the defect rate after molding.

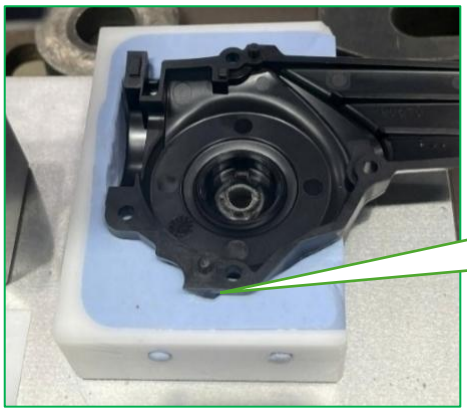
❖ **Evaluation of the Drilling Operation**

- The operator must manually control the lever to move the drill bit downward for machining. As a result, the processing time depends on the operator's handling speed, leading to a longer machining time.



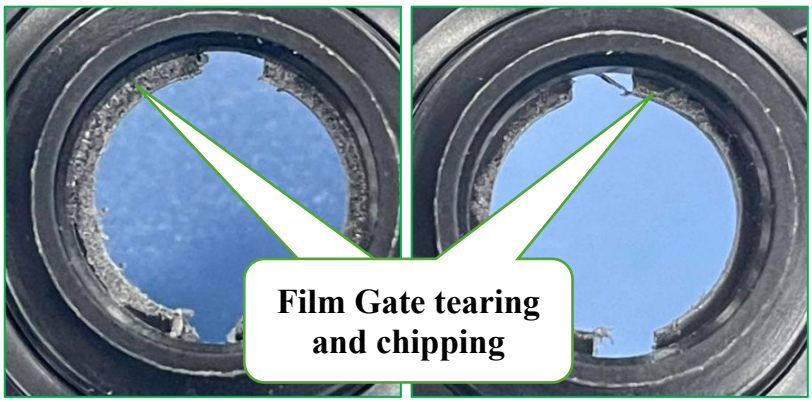
Manually operate the lever for machining

- The product surface is in direct contact with the fixture during the machining process, making it susceptible to scratches and affecting the appearance quality of the product.

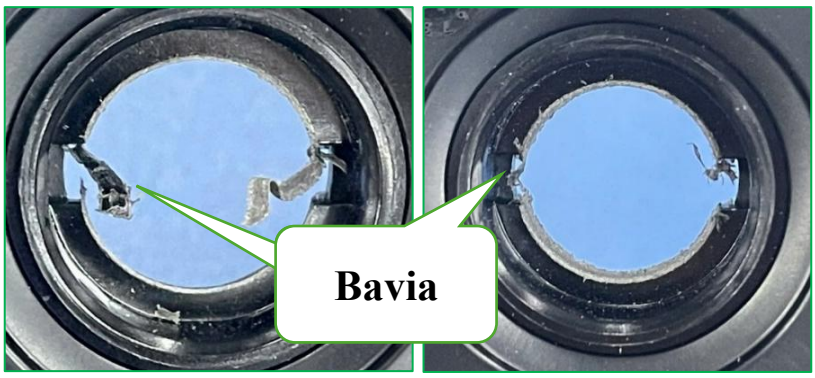


The product surface is in direct contact with the fixture.

- Tool wear at high production volumes may prevent complete Film Gate cutting, resulting in deformation and Film Gate tearing.



- Burrs are likely to occur at the two bearing locating positions during machining due to direct contact with the tool and fixture.



❖ **Fishbone Diagram of the Causes of Processing Waste in the BODY COVER 6Q4908 Process**

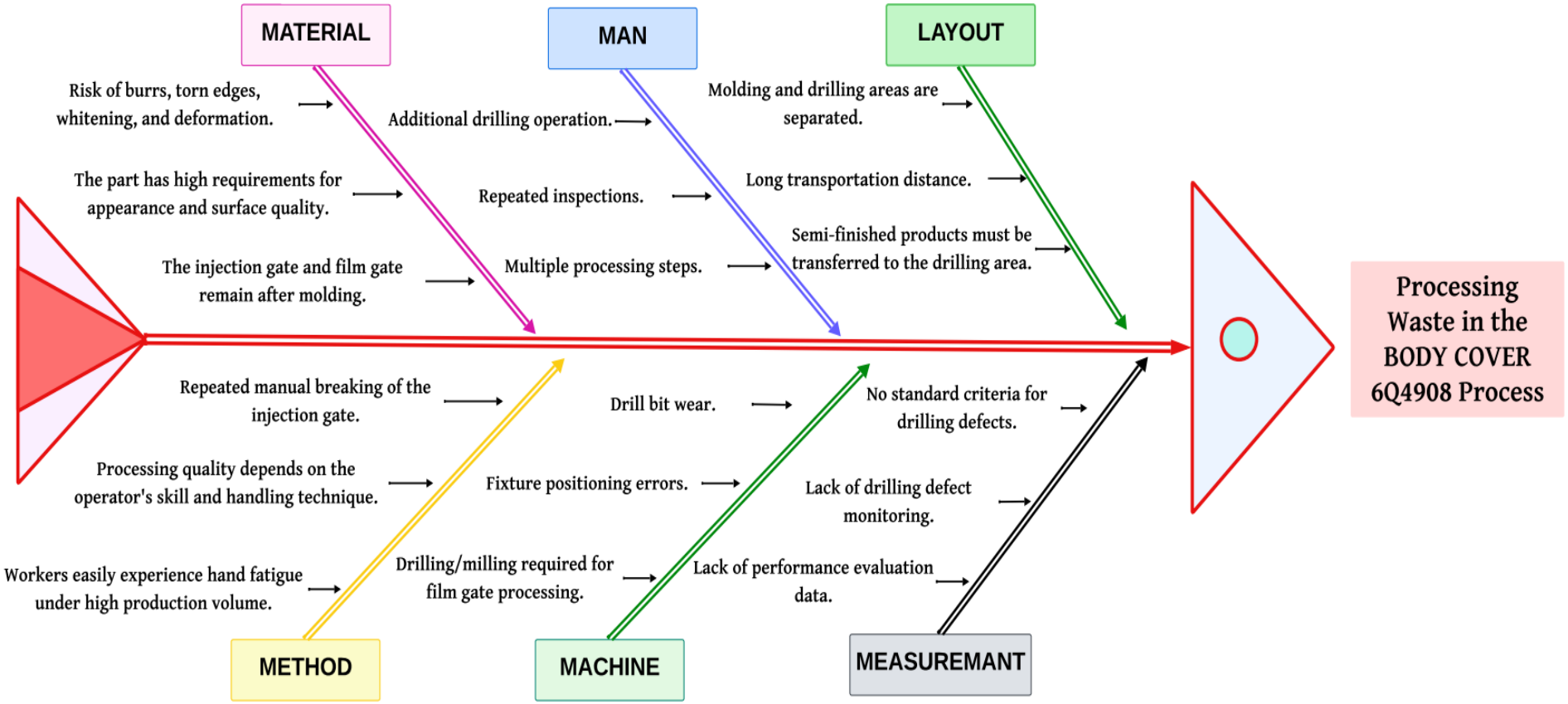


Figure 3.6. Fishbone Diagram of the Causes of Processing Waste in the BODY COVER 6Q4908 Process

3.5.4. Actual Cycle Time of the BODY COVER 6Q4908 Manufacturing Process

Table 3.6. Actual Cycle Time of the BODY COVER 6Q4908 Manufacturing Process

NO.	Process	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	Average
1	Take DSP-46 material and load it onto the cart	5	5	6	5	4	5	5	6	5	5	**5,1**
2	Move to the required production machine	104	106	105	108	103	105	107	104	106	105	**105,3**
3	Pour DSP-46 material into the container	24	25	26	25	24	25	27	25	26	25	**25,2**
4	Close the container lid and start the Drying Hopper to transfer resin into the machine	8	8	9	8	7	8	8	9	8	8	**8,1**
5	Record the daily resin-loading log	20	21	20	19	20	22	20	21	19	20	**20,2**
6	Move back to the warehouse	106	104	105	107	103	106	105	104	106	105	**105,1**
7	Automatic production machine	42	43	42	41	42	44	42	43	41	42	**42,2**
8	Manually break the injection gate	3	3	4	3	3	3	4	3	3	3	**3,2**
9	Visual inspection	2	2	2	3	2	2	2	2	3	2	**2,2**
10	Place into basket	2	2	3	2	2	2	2	3	2	2	**2,2**
11	When the lot is complete, move to the drilling area	178	181	180	183	179	182	180	181	177	180	**180,1**
12	Take the product and place it into the drilling jig	2	2	2	3	2	2	2	2	3	2	**2,2**
13	Drilling operation	4	4	5	4	4	4	5	4	4	4	**4,2**
14	Unload product	2	2	2	2	3	2	2	2	2	3	**2,2**
15	Visual inspection	2	2	3	2	2	2	2	3	2	2	**2,2**
16	Place into basket	2	2	2	3	2	2	2	2	3	2	**2,2**
	Lead Time											**511,9**

The time study results show that the average Lead Time of the current manufacturing process for BODY COVER 6Q4908 is 511,9 seconds. The measured data show only small variations between observations, indicating that the collected data are reliable and accurately represent the current production condition. The analysis shows that the longest process times mainly come from transportation and waiting activities. Specifically, moving products to the drilling area takes an average of 180,1 seconds, transporting raw materials from the warehouse to the production machine takes 105,3 seconds, and returning to the warehouse takes 105,1 seconds. The total time of these three activities is 390,5 seconds, accounting for approximately 76,28% of the total Cycle Time. In contrast, direct processing operations such as injection molding and drilling account for only a small portion of the total cycle time. These results indicate that most of the current process time is spent on transportation and waiting activities rather than on activities that directly create the product. This provides an important basis for further value stream analysis and for identifying improvement opportunities in the following sections of the study.

3.6. Current Value Stream Mapping of the V120 Department

To develop the Current State Value Stream Mapping (VSM) for the material supply and post-molding processes in the V120 Department, the research team collected the basic operational parameters of the production system. These parameters serve as the basis for calculating indicators related to production time, production capacity, and flow efficiency. In addition, they provide essential information for analyzing and evaluating the current state as well as constructing the Current State Value Stream Map.

No.	Parameter	Value
1	Annual Production Demand	43.158 products/year
2	Monthly Production Demand	3.597 products/month
3	Number of Working Shifts	3 shifts/day
4	Working Time per Shift	8 hours/shift (480 minutes/shift)
5	Break Time	45 minutes/shift
6	Available Production Time (APT)	1.305 minutes/day

Table 3.7. Summary of Data Used for Current State Value Stream Mapping in the V120 Department

NO.	Process Stage	OP (persons)	CT (s)	VA (s)	NVA (s)	CO (min)	APT (min)	AOP (min)	UP (%)
1	Take DSP-46 material and load it onto the cart	1	5,1	0	5,1	0	1.305	1.305	100
2	Move to the required production machine		105,3	0	105,3	0	1.305	1.305	100
3	Pour DSP-46 material into the container		25,2	20.2	5	0	1.305	1.305	100
4	Close the container lid and start the Drying Hopper to transfer resin into the machine		8,1	0	8,1	0	1.305	1.305	100
5	Record the daily resin-loading log		20,2	0	20,2	0	1.305	1.305	100
6	Move back to the warehouse		105,1	0	105,1	0	1.305	1.305	100
7	Automatic production machine	1	42,2	42,2	0	30	1.305	1.275	97,70
8	Manually break the injection gate	1	3,2	2,2	1	0	1.305	1.305	100
9	Visual inspection		2,2	1,5	0,7	0	1.305	1.305	100
10	Place into basket		2,2	1	1,2	0	1.305	1.305	100
11	When the lot is complete, move to the drilling area	1	180,1	0	180,1	0	1.305	1.305	100
12	Take the product and place it into the drilling jig	1	2,2	1	1,2	0	1.305	1.305	100
13	Drilling process		4,2	3,2	1	10	1.305	1.295	99,23
14	Unload product		2,2	1	1,2	0	1.305	1.305	100
15	Visual inspection	1	2,2	1,5	0,7	0	1.305	1.305	100
16	Place into basket		2,2	1	1,2	0	1.305	1.305	100

From the actual observations, the production process consists of detailed operations as shown in the previous table. For the convenience of constructing the Current State Value Stream Map (VSM), these operations were grouped into eight main processes. This grouping does not change the original data because the processing time shown in the data box of each process on the VSM is calculated as the sum of the corresponding operation times.

- Material Picking at Warehouse V120-1
- Move to the Required Production Machine
- Load Raw Materials into the Machine
- Move Back to the Warehouse
- Automatic Plastic Molding
- Preliminary Post-Molding Processing
- Move to the Drilling Area
- Drilling and Finishing

In particular:

Load Raw Materials into the Machine consists of three operations: Pour DSP-46 material into the container (25,2 s), Close the container lid and start the Drying Hopper to transfer resin into the machine (8,1 s), Record the daily resin-loading log (20,2 s). The total process time is 53,5 seconds. Preliminary Post-Molding Processing consists of three operations: Manually break the injection gate (3,2 s), Visual inspection (2,2 s), and Place into basket (2,2 s). The total process time is 7,6 seconds. Drilling and Finishing consists of five operations: Take the product and place it into the drilling jig (2,2 s), Drilling process (4,2 s), Unload product (2,2 s), Visual inspection (2,2 s), and Place into basket (2,2 s). The total process time is 13 seconds. Transportation activities, including Move to the Required Production Machine, Move Back to the Warehouse, and Move to the Drilling Area, are maintained as separate processes in the VSM to highlight Non-Value-Added (NVA) activities and accurately reflect the factors contributing to the increase in Lead Time throughout the value stream.

From the data table above, the current Value Stream Mapping (current VSM) is established. The current Value Stream Mapping helps visualize the flow of materials, process time, and parameters of the production line, serving as a foundational basis for identifying existing waste within the line.

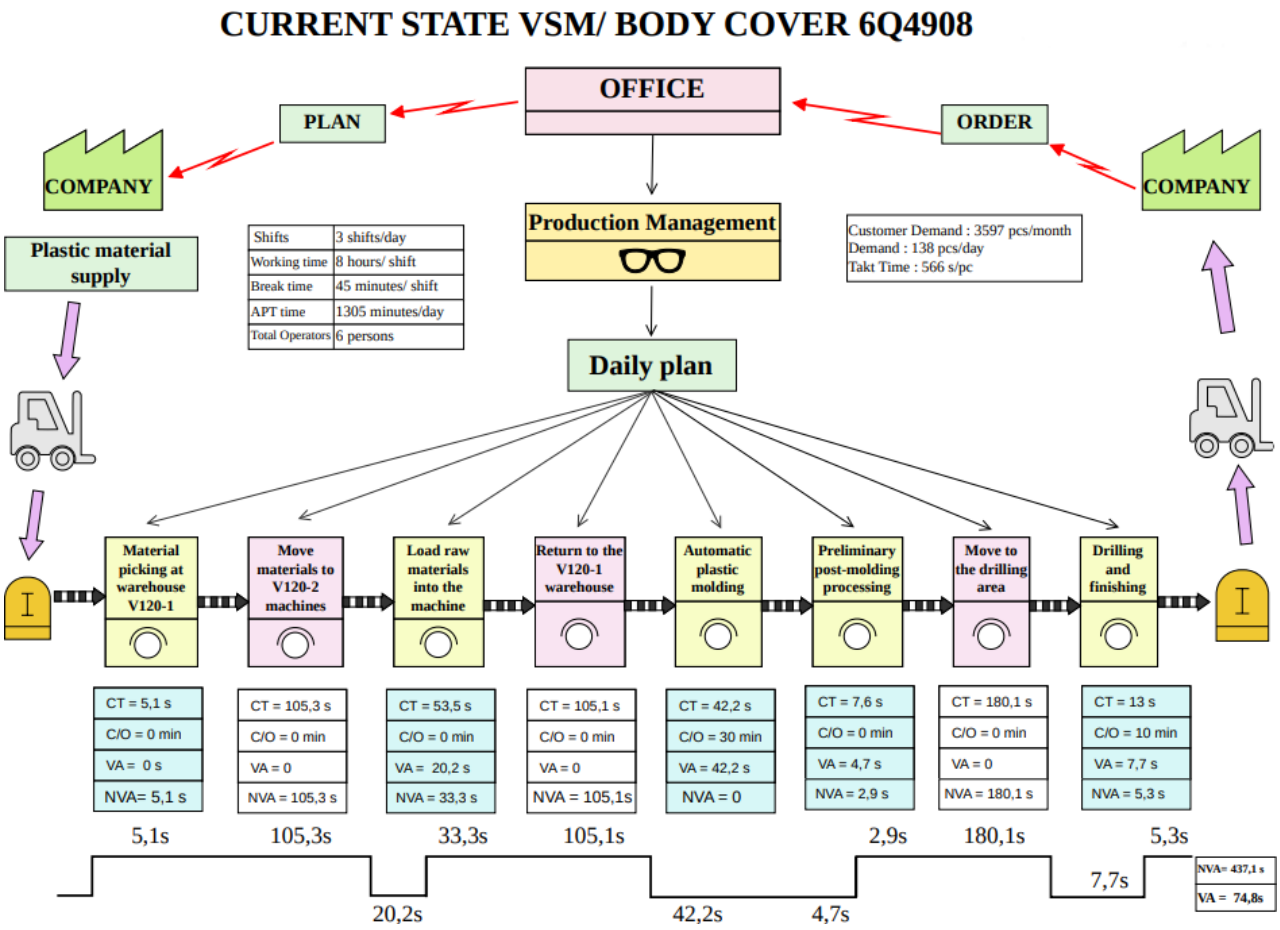


Figure 3.7. Current-State Value Stream Map (VSM) of Material Supply and Manufacturing Flow for BODY COVER 6Q4908

The analysis of the current Value Stream Mapping (VSM) shows that the total Value-Added (VA) time of the production process is only 74,8 seconds, while the Non-Value-Added (NVA) time reaches 437,1 seconds. This corresponds to approximately 14,6% VA and 85,4% NVA of the total value stream time. The results indicate that the main bottleneck of the system does not lie in the primary manufacturing operations, such as injection molding or drilling, but rather in the way material flow is organized within the factory. Specifically, raw materials are stored far from the production area, while the Film Gate processing operation is carried out in a separate area after the molding process. As a result, additional internal transportation activities are required, interrupting the product flow and increasing process time. Consequently, non-value-added activities account for a significant portion of the total process time, reducing production efficiency and extending the overall lead time.

Based on the current-state analysis, two main improvement opportunities have

been identified. The first is to reduce material transportation waste between V120-1 and V120-2 by optimizing material storage according to the ABC classification principle. The second is to reduce transportation waste, unnecessary handling, and quality-related risks in the Film Gate processing operation by evaluating the replacement of the current drilling method with a stamping process. These improvement proposals will be presented and evaluated in detail in Chapter 4.

Chapter 4: Future-State Value Stream Design and Proposed Improvement Solutions

4.1. Layout Improvement for the Temporary Raw Material Storage Area at V120-2

4.1.1. Basis and Objectives of the Proposed Solution

Based on the current-state analysis of the V120 department, raw materials used for the nine injection molding machines at V120-2 are currently stored mainly in the warehouse located in the V120-1 area. When the injection molding machines at V120-2 require materials, workers must travel from the main warehouse to the machine area to supply them. This travel route is repeated many times during the day, resulting in long transportation distances, increased non-value-added time, and extended Lead Time in the production process.

According to the current-state measurement results, the distance from the main warehouse to the injection molding machines at V120-2 ranges from approximately 64,5 m to 92,3 m, depending on machine location. In addition, the travel time from the warehouse to the machine is 105 seconds, and the return travel time to the warehouse is 105 seconds, totaling 210 seconds for one material supply cycle. This is considered transportation waste because the movement activity does not directly add value to the product.

Based on the above issue, the proposed solution is to establish a temporary raw material storage area at V120-2. This area functions as a sub-warehouse or quick supply point, used to store a sufficient quantity of raw materials for the types of plastic resin frequently used at V120-2. This solution does not completely replace the main warehouse at V120-1 but aims to shorten the material supply distance from the storage area to the injection molding machines, reduce travel time, and improve material flow.

The objective of this solution is to reduce transportation distance, reduce material supply time, minimize machine waiting time for materials, and eliminate unnecessary operations in the material supply process. At the same time, arranging materials in fixed locations also helps workers find, take, and check materials more easily while reducing the risk of supplying incorrect materials. The effectiveness of the solution

will be evaluated through indicators such as material supply distance, material supply time, number of trips per day, total time saved per day, and transportation time reduction rate.

4.1.2. Calculation of the Required Area for the Temporary Raw Material Storage Area at V120-2

To arrange the temporary raw material storage area at V120-2, the capstone project is based on the actual available space that can be utilized within the production area. According to the layout survey, the vacant area expected to be used for temporary raw material storage is approximately 6 m². Based on this area, the project determines the number of pallets that can be arranged to support quick material supply for the injection molding machines at V120-2.

Raw materials are stored on pallets. Each pallet has a standard size of 1,1 m x 1,1 m. Therefore, the occupied area of one pallet is calculated as follows:

$$\text{Area of one pallet} = 1{,}1 \times 1{,}1 = 1{,}21 \text{ m}^2$$

With the arrangement of 4 pallets, the direct pallet placement area is calculated as follows:

$$\text{Area for 4 pallets} = 4 \times 1{,}21 = 4{,}84 \text{ m}^2$$

In this arrangement, the 4 pallets are placed close together, with no gap between pallets. Therefore, 4,84 m² is the direct occupied area of the pallet group. The remaining area within the 6 m² space is used as an external operating space around the pallet group, allowing access for hand trolleys, material handling by workers, resin code checking, identification labeling, and compliance with 5S requirements.

The remaining operating area is calculated as follows:

$$\text{Remaining operating area} = 6 - 4{,}84 = 1{,}16 \text{ m}^2$$

Thus, with an available area of approximately 6 m², this area can accommodate 4 pallets for temporary raw material storage. Of this area, 4,84 m² is used for pallet placement, while the remaining approximately 1,16 m² is used for operating space, hand trolley access, and material management. This arrangement is more suitable

than leaving gaps between individual pallets, as it helps utilize the floor space effectively while still ensuring external operating space.



Figure 4.1. Arrangement of temporary raw material pallet locations at V120-2

After determining the required area, the temporary raw material storage area was designed with four fixed pallet locations. Each location is marked with yellow floor lines to clearly identify the storage boundaries and ensure compliance with 5S principles. In addition, a material identification board is installed at each pallet location to support material management, inventory control, and material issuing activities. Standardizing the storage area enables operators to easily locate and retrieve materials while reducing the risk of supplying incorrect materials during the production process.

4.1.3. Determination of Storage Requirements and Temporary Raw Material Pallet Arrangement at V120-2

To determine the storage requirements for the temporary raw material storage area at V120-2, the capstone project collected and summarized daily raw material consumption data for March 2026. The data table shows the usage quantity of each

material type, including DSP-53, DSP-46, ABS-S, S.E.B.S, RUN-GR1, ABS-P, and PP-M, for each production day.

Table 4.1. Raw Material Usage Table for March 2026

DAILY MATERIAL CONSUMPTION - MARCH 2026 (kg)								
Date	**DSP-53**	**DSP-46**	**ABS-S**	**S.E.B. S**	**RUN-GR1**	**ABS-P**	**PP-M**	**Total**
3/2/2026	175	200	50	75	0	150	100	750
3/3/2026	75	12	0	25	0	225	50	500
3/4/2026	100	225	0	50	0	125	100	600
3/5/2026	125	150	0	0	0	150	100	525
3/6/2026	50	200	50	100	0	250	100	750
3/7/2026	100	50	25	0	0	375	268	818
3/8/2026	150	0	0	25	0	350	0	525
3/9/2026	150	104	75	75	0	275	125	804
3/10/2026	150	100	25	25	0	200	75	575
3/11/2026	100	100	50	75	0	325	100	750
3/12/2026	175	0	25	50	0	325	0	575
3/13/2026	25	50.8	0	50	0	275	50	450.8
3/14/2026	50	139	50	25	0	125	75	464
3/15/2026	75	50	0	75	0	150	75	425
3/16/2026	150	225	25	25	0	0	0	425
3/17/2026	25	150	50	75	0	175	50	525
3/18/2026	100	125	25	25	0	75	50	400
3/19/2026	100	225	50	75	0	150	50	650
3/20/2026	75	150	75	50	0	75	50	475
3/21/2026	75	250	25	75	0	75	0	500
3/22/2026	75	400	25	25	0	50	50	625
3/23/2026	25	275	25	75	0	75	200	675
3/24/2026	75	325	0	50	0	125	125	700
3/25/2026	125	150	75	50	0	100	75	575
3/26/2026	50	0	0	50	0	225	175	500
3/27/2026	125	125	50	0	0	125	50	475
3/28/2026	75	250	0	0	0	100	125	550
3/29/2026	200	300	25	50	0	125	150	850
3/30/2026	50	100	0	25	0	125	125	425
Total	**2.825**	**4.543,8**	**800**	**1.300**	**0**	**4.900**	**2.493**	**16.861,8**

Based on the daily raw material consumption data for March 2026, the total quantity of raw materials used during the period was 16.861,8 kg. The number of days with recorded raw material consumption in the dataset was 29 days.

The average daily raw material consumption is calculated as follows:

16.861,8 kg / 29 days = 581,44 kg/day

The proposed temporary storage area has sufficient space to accommodate four pallets. According to the storage specification, each plastic resin bag weighs 25 kg, and each pallet can store a maximum of 40 bags, equivalent to:

40 bags x 25 kg = 1.000 kg/pallet

Therefore, the total storage capacity of four pallets is:

4 pallets x 1.000 kg = 4.000 kg

Based on the actual storage capacity and the average daily consumption rate, the number of storage days is calculated as follows:

4.000 kg / 581,44 kg/day = 6,88 days

Thus, the storage area with a capacity of four pallets can support raw material consumption for approximately 6,9 days, equivalent to about 7 days of production based on the average consumption rate.

In addition, considering the highest daily consumption recorded in the dataset, which was 850 kg/day, the storage duration under peak consumption conditions is calculated as follows:

4.000 kg / 850 kg/day = 4,7 days

Therefore, under peak consumption conditions, the storage area can support approximately 4 to 5 days of production.

In conclusion, with space available for four pallets, the maximum storage capacity is 4.000 kg of raw materials, equivalent to 160 bags. The storage capacity can support approximately 7 days of production based on average consumption and approximately 4 - 5 days based on peak consumption. Therefore, the arrangement of four pallets is considered appropriate for short-term storage and can effectively support production requirements for approximately one working week.

4.1.4. ABC Analysis of Raw Materials at V120-2

To identify the raw materials that should be prioritized for storage in the V120-2 material waiting area, an ABC analysis was conducted based on material consumption data. The consumption data were collected from production activities at V120-2 during March 2026. The analysis results are presented in Table 4.2 and Figure 4.2

Table 4.2. ABC Analysis Results of Raw Materials at V120-2

Rank	Material	Consumption (kg)	Percentage (%)	Cumulative Percentage (%)	ABC Category
1	ABS-P	4.900	29,06	29,06	A
2	DSP-46	4.543,8	26,95	56,01	A
3	DSP-53	2.825	16,75	72,76	A
4	PP-M	2.493	14,78	87,55	B
5	S.E.B. S	1.300	7,71	95,26	B
6	ABS-S	80	4,74	100	C
7	RUN-GR1	0	0	100	C

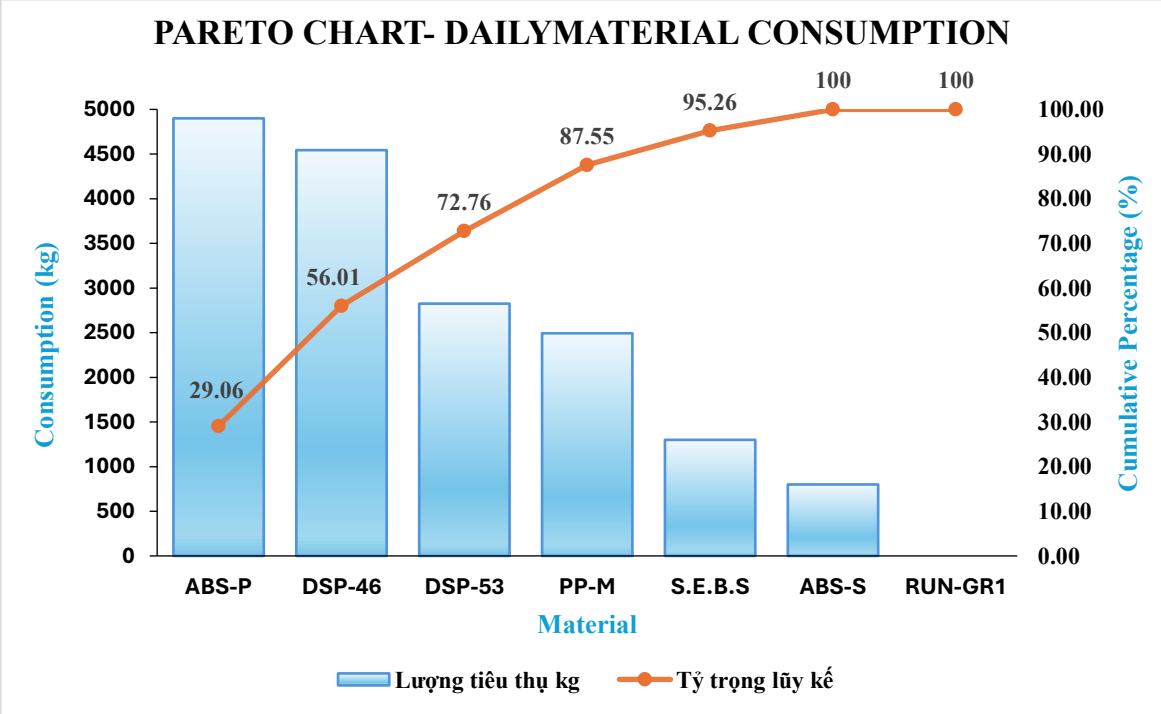


Figure 4.2. Pareto Chart of Raw Material Consumption at V120-2

The ABC analysis results show that material consumption at V120-2 in March 2026 was mainly concentrated in three materials: ABS-P, DSP-46, and DSP-53. These materials accounted for 72,76% of the total consumption and were classified as Category A. Therefore, they should be prioritized for storage in the V120-2 material waiting area to ensure quick material supply for production. Category B consists of PP-M and S.E.B.S, accounting for 22,50% of total consumption. These

materials have a moderate usage rate and can be stored flexibly according to the production schedule. Category C includes ABS-S and RUN-GR1, which account for only 4,74% of total consumption. In particular, RUN-GR1 was not used during the survey period. Therefore, these materials do not need to be stored regularly in the material waiting area and can remain in the main warehouse until required for production.

Table 4.3. Proposed Pallet Allocation for the Material Waiting Area at V120-2

Pallet Position	Material
Pallet 1	ABS-P
Pallet 2	DSP-46
Pallet 3	DSP-53
Pallet 4	PP-M hoặc S.E.B.S, ABS-S và RUN-GR1 (Flexible according to production schedule)

This arrangement ensures that frequently used materials are readily available at the production area, helping to reduce material supply time, minimize transportation waste, and improve material flow efficiency. At the same time, it makes effective use of the existing storage space available at V120-2.

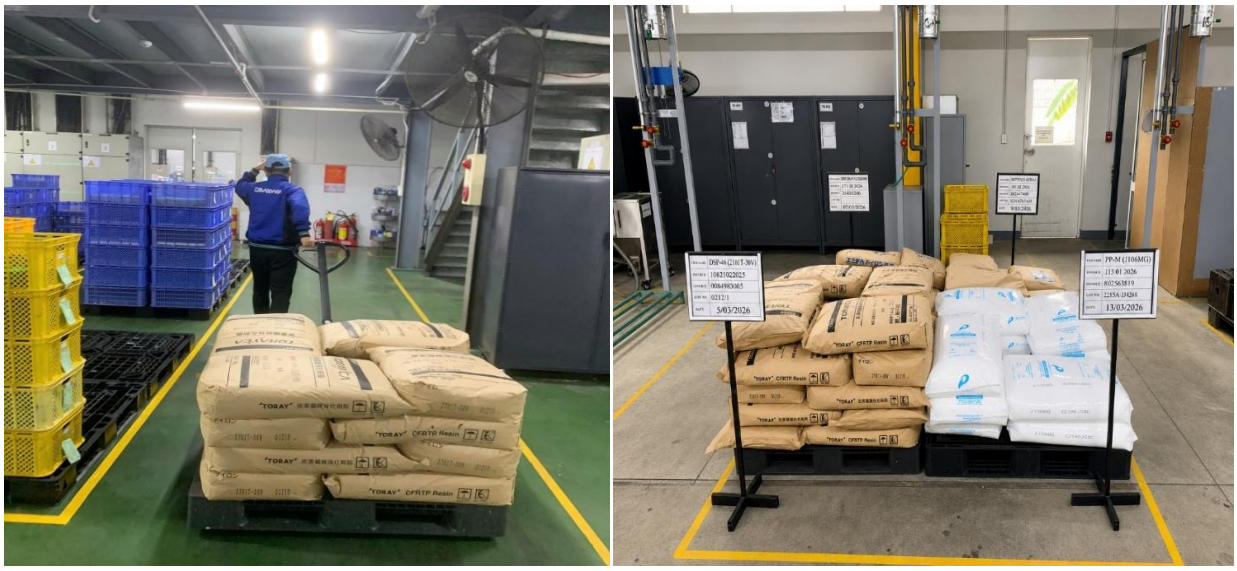


Figure 4.3. Material Transportation and Storage Layout

4.1.5. Measurement of Material Supply Time and Distance after Improvement

Table 4.4. Measurement of Material Supply Time and Distance after Improvement

NO.	Current material supply route	Receiving machine	One-way distance (m)	Two- way distance (m)	Moving time (s)	Resin picking time (s)	Material loading time (s)	Return time (s)	Total time per cycle (s)	Feeding frequency per day	Total distance per day (m)	Total time per day (s)
01	V120-2 Waiting Area → V120-2 Machines	SE100-06	19,3	38,6	29	10	25	19,3	83,3	3	115,9	249,8
02	V120-2 Waiting Area → V120-2 Machines	SE130-01	21,5	42,9	32,2	10	25	21,5	88,7	3	128,8	266
03	V120-2 Waiting Area → V120-2 Machines	SE130-02	22,7	45,4	34,1	10	25	22,7	91,8	3	136,3	275,4
04	V120-2 Waiting Area → V120-2 Machines	SE180	24,6	49,2	36,9	10	25	24,6	96,5	3	147,7	289,6
05	V120-2 Waiting Area → V120-2 Machines	SE100-01	17,2	34,4	25,8	10	25	17,2	78	3	103,2	234
06	V120-2 Waiting Area → V120-2 Machines	SE100-02	18,4	36,8	27,6	10	25	18,4	81	3	110,4	243
07	V120-2 Waiting Area → V120-2 Machines	SE100-03	19,5	38,9	29,2	10	25	19,5	83,7	3	116,8	251
08	V120-2 Waiting Area → V120-2 Machines	SE100-04	17,3	34,7	26	10	25	17,3	78,3	3	104	235
09	V120-2 Waiting Area → V120-2 Machines	SE100-05	18,3	36,5	27,4	10	25	18,3	80,7	3	109,6	242

The one-way distance from the temporary raw material storage area at V120-2 to the injection molding machines ranges from 17,2 m to 24,6 m. Each machine receives material replenishment an average of three times per day, equivalent to 27 material supply trips per day for all nine machines. Compared with the previous material supply method from the V120-1 warehouse, the transportation route has been significantly shortened because the material storage location has been moved closer to the production area.

The total material transportation distance after improvement is 1.072,7 m/day, equivalent to approximately 1,07 km/day. The total material supply time is 2.286,4 seconds/day, equivalent to 38,11 minutes/day. Dividing this by 27 supply trips, each material supply cycle takes approximately 84,68 seconds. These results indicate that the time spent on transportation activities has been significantly reduced, contributing to the elimination of non-value-added activities in the production process.

Among the nine machines receiving materials, SE180 has the longest distance at 24,6 m per one-way trip and a total material supply time of 289,6 seconds/day. In contrast, SE100-01 has the shortest distance at 17,2 m per one-way trip and a total material supply time of 234 seconds/day. Although differences in machine locations still exist, the establishment of the temporary raw material storage area at V120-2 has significantly reduced the impact of transportation distance and improved the continuity of material flow throughout the production area.

4.1.6. Layout after Improvement

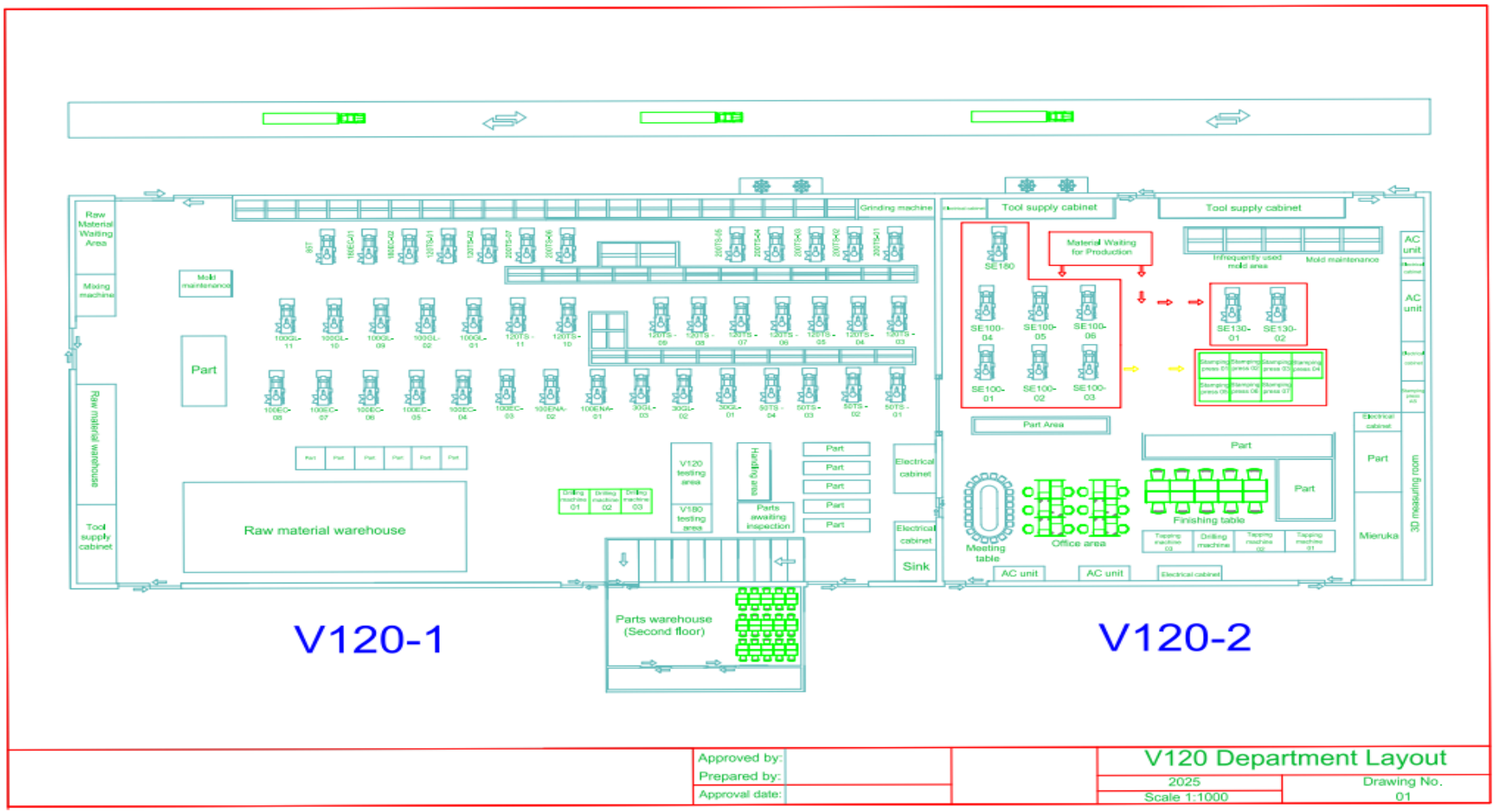


Figure 4.4. Layout of the V120 Department after Improvement

4.2. Processing Technology Conversion

Based on the current-state analysis, the BODY COVER 6Q4908 – model S331 product still has the gate and Film Gate remaining after the injection molding process, which need to be removed. Before improvement, the product was processed using the drilling/milling method, in which operators had to manually break the gate, collect the products in baskets, and then move them to the drilling area for finishing. This process involved many manual operations, additional movement time, and quality defect risks.

4.2.1. Study on the Feasibility of Converting Film Gate Processing Technology from Drilling to Stamping for BODY COVER 6Q4908

To evaluate the feasibility of converting the processing technology from drilling to stamping for the BODY COVER 6Q4908 product, the capstone project conducted a survey and classification of the existing stamping equipment capacity in the factory.

Table 4.5. Summary of Punch Tip and Punch Pin Specifications for the BODY – BODY COVER Product Group

NO.	PART NAME	PART NO	MODEL	Die Size (mm)	Punch Size (mm)	Product Group
1	BODY	6G9758	A902	16 (0,01/0,05)	12,10	A
2	BODY	6G9841	A900			
3	BODY	6G9862	A904			
4	BODY	6Q0687	S134			
5	BODY	6Q0715	S137			
6	BODY	6Q0744	S131			
1	BODY	6H0182	A961	11 (0,01/0,04)	9,10	B
2	BODY	6Q1611	S262			
3	BODY	6Q1733	S261			
4	BODY	6Q1952	S293			
5	BODY	6Q2023	S291			
1	BODY COVER	6Q1960	S293	13 (0,01/0,04)	10,10	C
2	BODY COVER	6Q2027	S191			
3	BODY COVER	6Q1623	S262			
4	BODY COVER	6Q1738	S261			
1	BODY COVER	6Q1755	S265	14 (0,01/0,04)	11,1	D
2	BODY COVER	6Q2062	S295			

3	BODY COVER	6Q5339	S409			
1	BODY COVER	6Q1889	S268	17 (0,01/0,04)	13,1	E
2	BODY COVER	6Q2165	S298			
3	BODY COVER	6Q2601	S270			
4	**BODY COVER**	**6Q4908**	**S331**			
1	BODY	6Q1331	S227	12 (0,01/0,04)	10,1	F
2	BODY	6Q1747	S264			
3	BODY	6Q2054	S294			

Table 4.6. List of Part Numbers Currently Processed by the Drilling Method

NO.	PART NAME	PART NO	MODEL	Drill Bit Diameter (mm)
1	BODY	6Q0365	S095	12,10
2	BODY	6Q2586	S270	13
3	BODY	6Q3621	S409	12,40
4	BODY	6Q4898	S331	13
5	BODY	6Q5338	S408	12,40
6	BODY	6Q7371	S533	13
7	BODY	6Q8832	S586	12,40
8	BODY COVER	6H3564	S044	12,10
9	BODY COVER	6Q0374	S095	12,10
10	BODY COVER	6Q1889	S267	13,20
11	BODY COVER	6Q2165	S297	13,20
12	BODY COVER	6Q2601	S270	13
13	**BODY COVER**	**6Q4908**	**S331**	**13**

The comparison of the two statistical data tables provides several important findings:

First, regarding the current distribution of processing technologies, most models in the BODY and BODY COVER product groups have already been standardized and assigned to the stamping process, which is further classified into Groups A to F according to the corresponding die and punch specifications shown in Table 4.5. In contrast, the number of part numbers that are still processed using the drilling method represents a significantly smaller proportion (as shown in Table 4.6) and mainly utilizes standard drill bit diameters of Ø12,10 mm, Ø12,40 mm, Ø13 mm, and Ø13,2 mm. This production practice clearly demonstrates that the stamping technology has

been well established and widely implemented within the factory, providing both practical experience and a solid technical foundation for extending its application to the remaining part numbers.

Second, with regard to the target improvement product, BODY COVER 6Q4908 (Model S331), the current Film Gate removal operation relies on the drilling process using a Ø13 mm drill bit. When compared directly with the stamping die classification data presented in Table 4.5, this product is fully compatible with and falls within Group E, which already has a standardized factory stamping die system with a Ø17 mm die and a Ø13,1 mm punch.

Third, from the perspective of geometric compatibility, the punch diameter of Group E (Ø13,1 mm) is almost identical to the diameter of the drill bit currently used in production (Ø13 mm). The existence of a suitable stamping die specification within a comparable product range serves as a key technical basis, effectively eliminating initial geometric design concerns and confirming that the target product can be converted to the stamping process with minimal technical risk.

Based on the above quantitative analysis, the BODY COVER 6Q4908 part is fully qualified and was selected as the representative product for piloting the Film Gate stamping process as a replacement for the current drilling method. The proposed technology conversion is expected to provide the following significant benefits:

- Process time optimization: Completely eliminates batch collection and intermediate transportation to a separate drilling area, thereby significantly reducing auxiliary operations and non-value-added (NVA) time.
- Improved product quality: Eliminates common quality defects associated with drilling operations, such as burr formation, film tearing, surface scratches, and machining position deviations.
- Enhanced process stability: The stamping operation, utilizing a dedicated positioning fixture and a punch that applies force directly to the Film Gate area, enables a faster, more accurate, and more stable processing cycle compared with the conventional drilling process.

4.2.2. Conditions for Applying the Stamping Method

To apply the stamping method, several technical conditions must be ensured.

a) The gate must be short

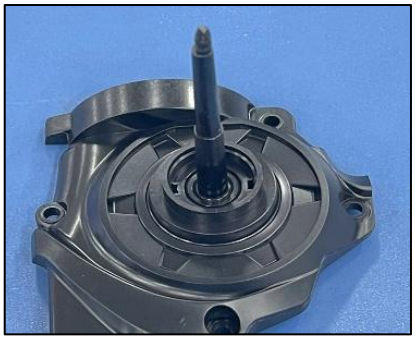


Figure 4.5. Product gate

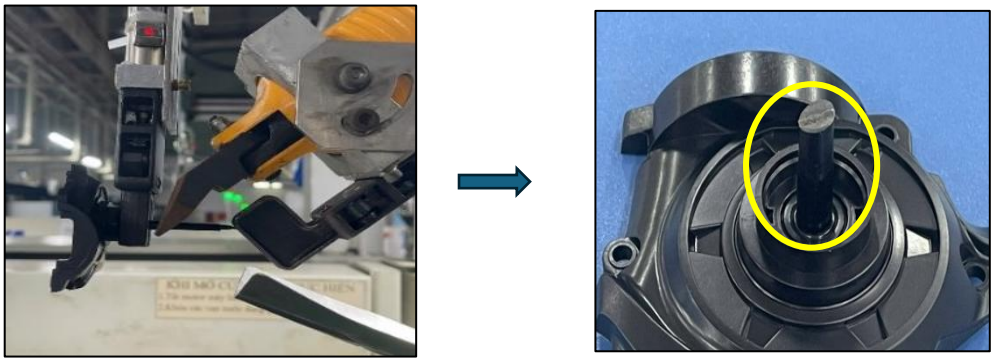


Figure 4.6. Product gate after robot cutting: 18 mm < gate relief hole length of the punch: 20 m

Before moving to the stamping process, the product gate must be shortened using a robot or cutting mechanism at the injection molding machine area. After robot cutting, the remaining gate length is approximately 18 mm, which is shorter than the 20 mm gate relief hole length of the punch. This allows the remaining gate section to fit into the relief hole of the stamping fixture, preventing interference, product lifting, or position misalignment during stamping. Therefore, the gate length after cutting meets the requirement for applying the stamping method.

b) The Film Gate can be processed

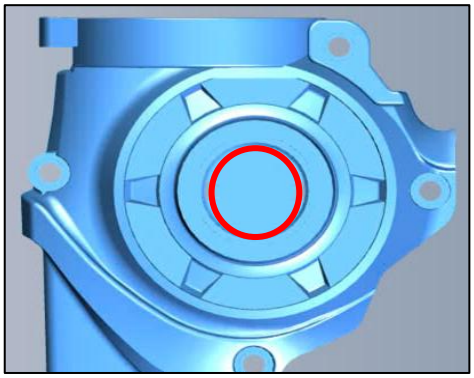


Figure 4.7. Film Gate requiring processing



Figure 4.8. The actual thickness is 1,5 mm; therefore, stamping is feasible

The second condition for applying the stamping method is that the Film Gate at the gate position must have a suitable size so that the punch can cut it effectively. Based on the actual inspection, the measured Film Gate thickness is approximately 1,5 mm. With this thickness, the Film Gate is not too thick and can be processed using the stamping method. Therefore, the BODY COVER 6Q4908 product meets the Film Gate size requirement for conversion from the drilling method to the stamping method.

c) The punch and die dimensions must be suitable for the required processing dimensions

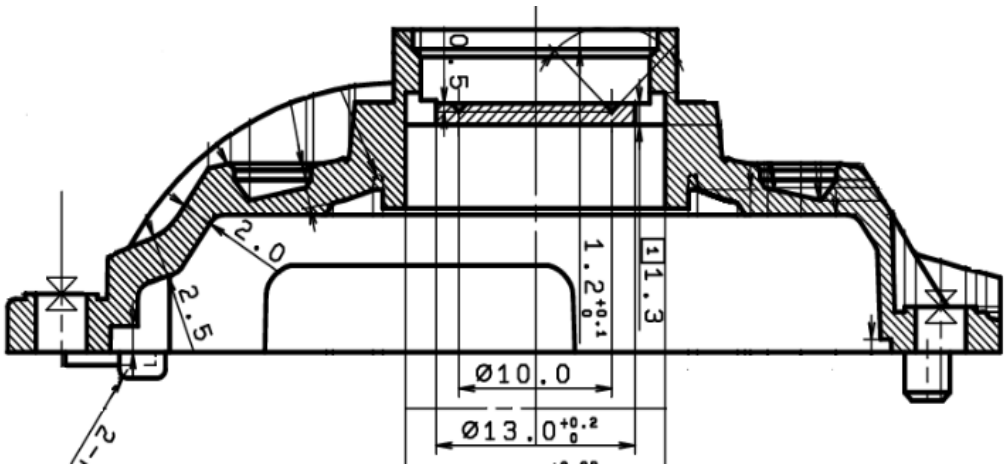


Figure 4.9. The required processing dimension is $Ø13^{+0.2}_{0}$ mm.

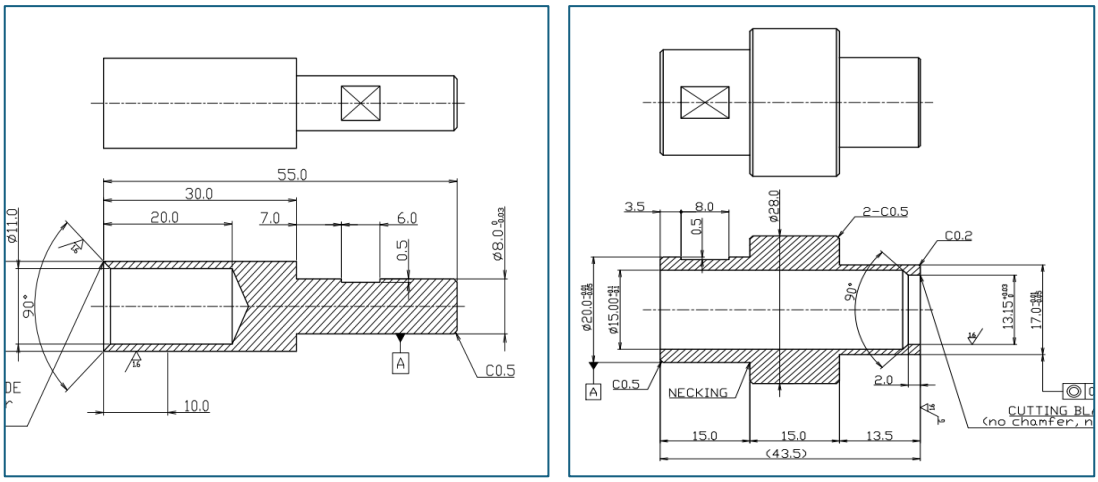


Figure 4.10. Design the punch and die dimensions to match the required processing dimension.

The third condition for applying the stamping method is that the punch and die dimensions must be suitable for the Film Gate area to be processed on the product. According to the technical drawing, the required processing dimension at the Film Gate position is Ø13 mm with a tolerance of +0,2/0, meaning that the processed dimension must be within the range of Ø13-Ø13,2 mm. Therefore, the punch tip and stamping die must be designed according to this dimension to ensure that the stamping process cuts at the correct position and profile without affecting the product surface. If the punch/die dimensions are not suitable, the product may be under-cut, over-cut, have burrs, or become deformed at the processed area. Therefore, designing the punch and die according to the required processing dimension is a mandatory condition for stable application of the stamping method.

d) A dedicated product fixture is available

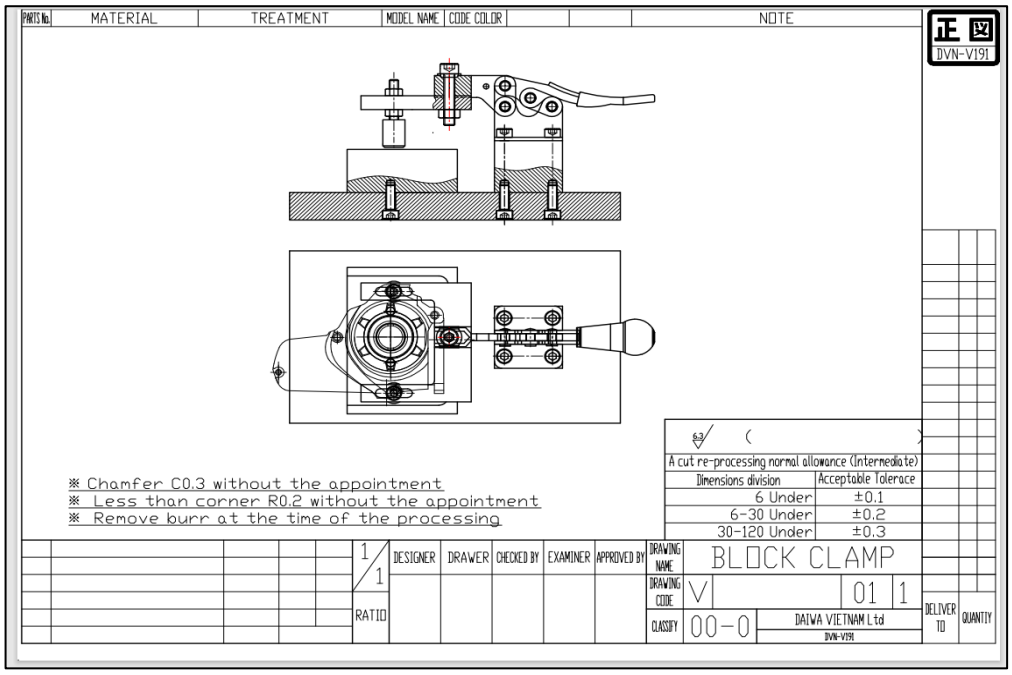


Figure 4.11. Prepare a manufacturing request form for the stamping jig

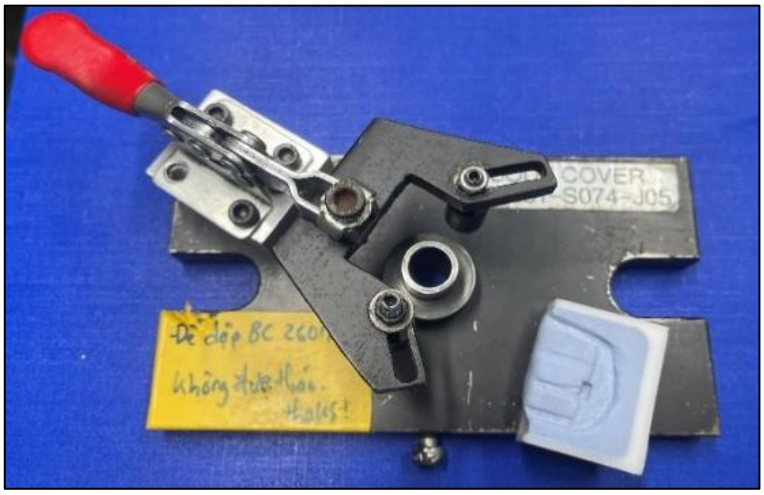


Figure 4.12. Stamping Jig

The fourth condition for applying the stamping method is that a product positioning jig must be available. The stamping jig is used to hold the product in the correct position during the stamping process, ensuring that the punch acts accurately on the Film Gate area to be processed. Before manufacturing the jig, drawings and a manufacturing request form must be prepared to define the dimensions, product positioning points, punch/die positions, clamping mechanism, and operation requirements. After the jig is manufactured, the BODY COVER 6Q4908 product is

placed into the jig and fixed before stamping. The use of the jig helps minimize position deviation, reduce the risk of burrs, scratches, or product deformation, and allows the operator to perform the operation more stably and repeatedly with higher accuracy.

e) The stamping machine must have sufficient capacity

The fifth condition for implementing the stamping method is that the stamping machine capacity must meet the required daily processing volume. Currently, the daily demand for BODY/BC stamping is approximately 20.000 pcs/day, while the capacity of the existing seven stamping machines is only about 13.000 pcs/day. Therefore, the current capacity has a shortage of approximately 7.000 pcs/day.

If additional equipment is not provided, the stamping process may become a new bottleneck, causing waiting time and affecting the production flow. Therefore, the department has ordered three additional stamping machines to increase the total number of machines to 10, ensuring that the stamping capacity can meet actual production requirements.

4.2.3. Periodic Maintenance Standards for Punches, Dies, and Stamping Jigs

Table 4.7. Periodic Maintenance Standards for Punches, Dies, and Stamping Jigs

Item	Inspection / Maintenance Content	Recommended Frequency	Action Criteria
Punch	Inspect for wear, edge chipping, plastic residue buildup, sharpness, and cutting surface uniformity.	At the beginning of each shift; cleaning at the end of each shift; detailed inspection/measurement weekly or based on cycle count.	If increased burrs, poor cut quality, or edge chipping are detected, stop operation for regrinding or replacement.

Die	Inspect die openings for burrs, surface wear, misalignment, or plastic debris accumulation.	Weekly; increase frequency during high production periods.	If product deformation or positional inaccuracies occur, check punch–die alignment and fit.
Stamping Jig	Inspect locating pins, contact surfaces, looseness, cleanliness, and scratches that may affect product surface quality.	At the beginning and end of each shift.	If the jig causes scratches or unstable positioning, clean, repair, or replace the locating components.
Stamping Machine	Inspect stamping force, stroke length, safety switches, emergency stop button, and overall operating condition.	According to the equipment maintenance schedule.	If stamping force becomes unstable or abnormal noise/vibration is observed, stop the machine for inspection.
Checklist	Record inspection date, inspector, tool condition, cycle count, and corrective actions taken.	Per shift, weekly, or monthly depending on the item.	Use as a database to correlate Tool Life, OEE, and NG Rate.

4.2.4. Post-Improvement Gate Stamping Process

After implementing the improvement solution, the Film Gate processing method was changed from drilling to stamping. The stamping operation was arranged directly in the production area to process the Film Gate immediately after the injection molding process. This change helps reduce manual operations, eliminate the need to transport semi-finished products to a separate processing area, and improve the continuity of the production flow. The post-improvement process consists of the following steps:

Table 4.8. Post-Improvement Gate Stamping Operation Steps

No.	Post-Improvement Operation Description
1	Automatic machine operation, robot cuts the gate
2	Place the product into the stamping fixture
3	Stamping operation
4	Remove the product from the fixture
5	Visual inspection
6	Place into basket

Compared with the current process, the stamping method simplifies the post-molding operations by eliminating the transportation of semi-finished products to the drilling area and reducing the number of intermediate processing steps. As a result, the product flow becomes more continuous and supports a more efficient production system in line with Lean Manufacturing principles.

Trial Implementation of the Post-Improvement BODY COVER 6Q4908 Gate Stamping Process and Result Evaluation

After identifying the necessary technical conditions for the gate stamping method, the capstone project conducted a trial implementation of the stamping process for the BODY COVER 6Q4908 product. The purpose of this trial was to verify the practical applicability of the stamping jig, stamping machine, and stamping operation under actual production conditions at the V120 department.

- Tools used:



Figure 4.13. Stamping Jig



Figure 4.14. Stamping machine

The trial process used two main types of equipment: a stamping jig and a stamping machine. The stamping jig is used to position and hold the product in the correct location during the stamping process, ensuring that the punch accurately acts on the Film Gate area to be processed. The stamping machine provides the pressing force required to remove the Film Gate according to the designed dimensions. The use of the stamping jig helps minimize positioning errors, reduce dependence on manual operations, and improve process stability.

The trial procedure consists of the following main steps:

Step 1: Place the product into the stamping jig



The operator takes the molded BODY COVER product and places it in the positioning area of the stamping jig. In this step, the product must be placed in the correct orientation and position so that the Film Gate area aligns with the punch and die positions.

Figure 4.15. Place the product into the stamping jig

Step 2: Stamping operation



After the product is stably positioned, the operator operates the stamping machine so that the punch moves down and acts on the Film Gate area. The Film Gate is cut off according to the profile of the punch and die. This step replaces the drilling/milling operation in the previous process.

Figure 4.16. Gate stamping operation

Step 3: Remove the product



After completing the stamping operation, the operator removes the product from the jig. The stamped product should be removed carefully to avoid scratching the surface or affecting the processed area.

Figure 4.17. Operation of removing the product from the stamping jig

Step 4: Visual Inspection



The operator inspects the stamped area, the product surface, and the surrounding Film Gate area. The inspection items include whether the processed area is acceptable, whether burrs are generated, and whether scratches or product deformation occur.

Figure 4.18. Visual inspection of the product

Step 5: Place the product into the basket



After passing inspection, the product is placed into the basket for transfer to the next process or to the semi-finished product storage area.

Figure 4.19. Place the product into the basket

The trial results show that the processed area after stamping meets the

requirements, the machined surface is clean, and no burrs are generated. In addition, the product surface does not have excessive direct contact with the jig during operation, which helps reduce the risk of scratches or appearance defects. This indicates that the stamping method is capable of ensuring processing quality for the BODY COVER 6Q4908 product.

In terms of process efficiency, the stamping method helps eliminate several unnecessary steps in the previous process, especially the movement of semi-finished products to the drilling area. When drilling is replaced by stamping, the operator no longer needs to transfer products to a separate drilling area, thereby reducing movement time, reducing batch waiting time, and making the post-molding product flow more continuous. In addition, the stamping operation is simpler than drilling, helping reduce dependence on operator skill and minimize the risk of milling tool wear during processing.

However, some points still need to be controlled continuously. At present, the new stamping machines have not been fully added, so when applied simultaneously to mass production, insufficient stamping machine capacity may occur. If the number of stamping machines is not sufficient compared with the required daily processing volume, the stamping process may become a new bottleneck, causing waiting time and affecting the production schedule. Therefore, stamping machines need to be added according to the plan, while manpower and operation standards should be arranged appropriately to ensure stable operation of the method.

Based on the trial results, it can be concluded that the gate stamping method for the BODY COVER 6Q4908 product is feasible. The stamped product meets appearance requirements, the processed area is clean, no burrs are generated, and the operation process is shortened compared with the drilling method. This method has been successfully tested and is currently being applied at V120. Therefore, the stamping method is selected as the improvement solution for the gate processing operation in the future-state VSM.

4.3. Development of the Future State Value Stream Map for the V120 Department

4.3.1. Basis for Developing the Future State VSM

The future-state Value Stream Mapping (VSM) was developed based on the improvement solutions proposed to enhance production flow efficiency in the V120 department. These improvements focus on optimizing material supply activities in

the V120-2 area and improving the Film Gate processing operation for the BODY COVER 6Q4908 product. For material supply activities, a material staging area was established in V120-2 to provide direct support for the injection molding machines. This arrangement helps shorten transportation distances and improve material supply responsiveness. For Film Gate processing, the stamping method was introduced to replace the current drilling method, allowing the operation to be performed directly in the production area and reducing the number of intermediate process steps. Based on these improvements, the future-state VSM was developed to illustrate the material and information flow after implementation and to evaluate the reduction of non-value-added activities as well as the overall improvement in production system performance.

4.3.2. Cycle Time After Improvement of the BODY COVER 6Q4908 Production Process

Table 4.9. Cycle Time After Improvement of the BODY COVER 6Q4908 Production Process

NO.	Process	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	Average
1	Take DSP-46 material and load it onto the cart	4	4	5	4	4	4	4	5	3	4	**4,1**
2	Move to the required production machine	22	23	21	22	22	23	21	22	23	22	**22,1**
3	Pour DSP-46 material into the container	25	26	24	25	25	26	24	25	26	24	**25,0**
4	Closethe container lid and start the Drying Hopper to transfer resin into the machine	8	8	9	8	7	8	8	9	7	8	**8,0**
5	Record the daily resin-loading log	20	21	19	20	20	21	19	20	20	20	**20,0**
6	Move back to the warehouse	22	21	23	22	22	21	23	22	21	23	**22,0**
7	Automatic production machine	42	43	41	42	42	43	41	42	42	42	**42,0**
8	Place the product onto the stamping fixture	2	2	2	2	2	2	2	2	2	2	**2,0**
9	Stamping operation	3	3	4	3	2	3	3	4	3	3	**3,1**
10	Unload product	2	2	2	2	2	2	2	2	2	2	**2,0**
11	Visual inspection	2	2	3	2	1	2	3	3	1	2	**2,1**
12	Place into basket	2	2	2	2	2	2	2	2	2	2	**2,0**
	Lead Time											**154,4**

The post-improvement time study results show that the average Cycle Time of the BODY COVER 6Q4908 production process was reduced to 154,4 seconds. The measured data show only minor variations between observations, indicating that the collected data are reliable and accurately represent the production conditions after improvement. Compared with the current state, the cycle time was significantly reduced through the implementation of a material staging area near the production line and the replacement of the drilling process with a stamping process. Transportation activities, which previously accounted for a large portion of the cycle time, were substantially reduced. Specifically, the time required to transport raw materials from the warehouse to the production machine decreased from 105,3 seconds to 22,1 seconds, while the return trip time decreased from 105,1 seconds to 22 seconds. In addition, the transportation of semi-finished products to the drilling area was completely eliminated. These results indicate that a significant portion of the non-value-added time in the process has been removed, contributing to a substantial reduction in the overall Cycle Time of the production flow.

4.3.3. Material Flow in the Future State VSM of the V120 Department

NO.	Process Stage	OP (persons)	CT (s)	VA (s)	NVA (s)	CO (min)	APT (min)	AOP (min)	UP (%)
1	Take DSP-46 material and load it onto the cart	1	4,1	0	4,1	0	1.305	1.305	100
2	Move to the required production machine		22,1	0	22,1	0	1.305	1.305	100
3	Pour DSP-46 material into the container		25	20	5	0	1.305	1.305	100
4	Close the container lid and start the Drying Hopper to transfer resin into the machine		8	0	8	0	1.305	1.305	100
5	Record the daily resin-loading log		20	0	20	0	1.305	1.305	100
6	Move back to the warehouse		22	0	22	0	1.305	1.305	100
7	Automatic production machine	1	42	42	0	30	1.305	1.275	97,7

NO.	Process Stage	OP (persons)	CT (s)	VA (s)	NVA (s)	CO (min)	APT (min)	AOP (min)	UP (%)
8	Take product and place in stamping base	1	2	0,8	1,2	0	1.305	1.305	100
9	**Stamping process**		3,1	2,1	1	10	1.305	1.295	99,23
10	Unload product		2	0,8	1,2	0	1.305	1.305	100
11	Visual inspection	1	2,1	1,4	0,7	0	1.305	1.305	100
12	Place into basket		2	1	1	0	1.305	1.305	100

The future-state VSM was developed based on two main improvement solutions: the establishment of a material staging area in V120-2 and the replacement of the drilling process with a stamping process. As a result, the production flow was simplified, the number of intermediate process steps was reduced, and unnecessary transportation activities were eliminated. In the future-state VSM, the operations of placing the product into the stamping fixture, performing the stamping process, removing the product from the fixture, conducting visual inspection, and placing the product into a basket are carried out consecutively within the same production area. Since no transportation or intermediate inventory occurs between these steps, they are grouped into a single process called “Stamping Process and Finishing”, with a total processing time of 11,2 seconds.

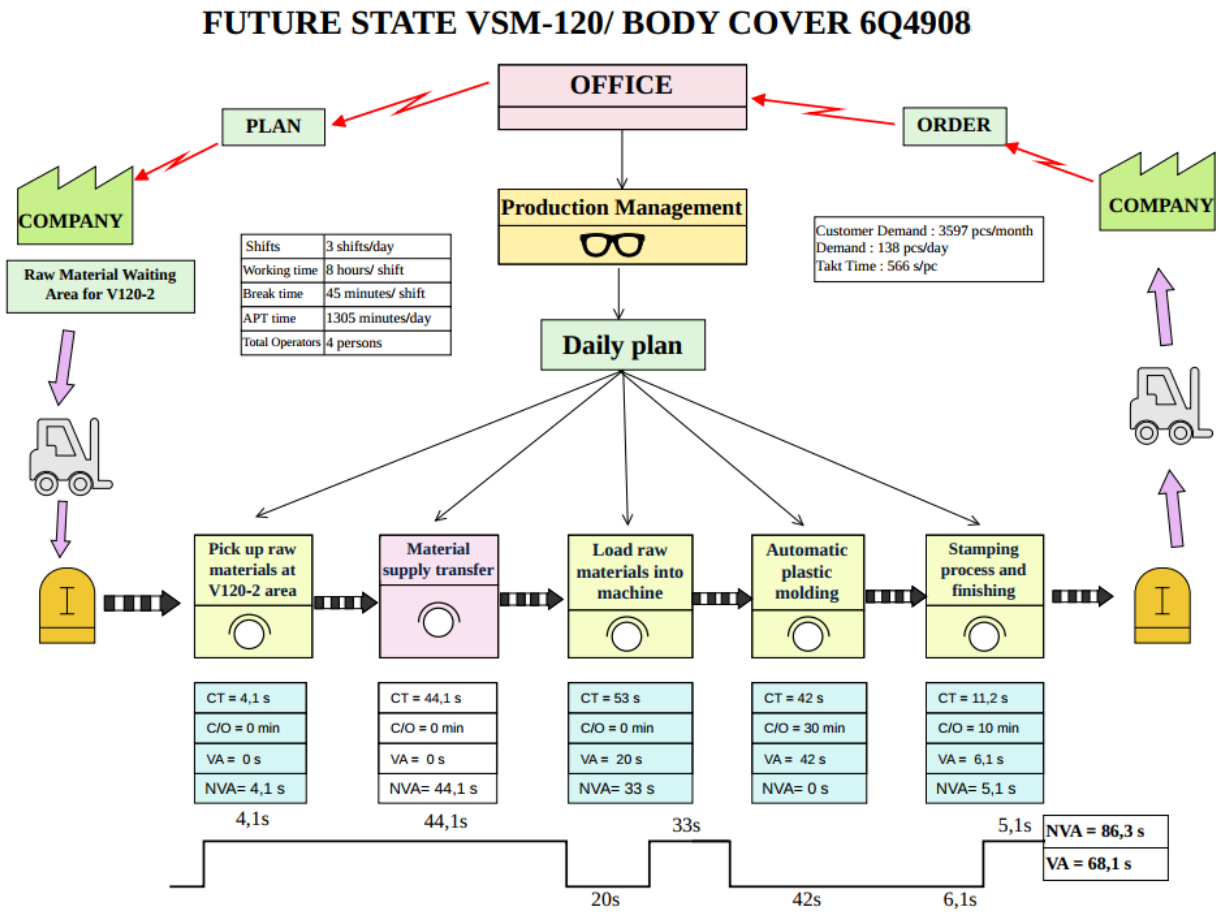


Figure 4.20. Future-State VSM of the Material Supply and BODY COVER 6Q4908 Manufacturing Process

The future-state VSM analysis shows that the total Lead Time of the production flow is 154,4 seconds. Of this, the Value-Added (VA) time is 68,1 seconds, accounting for approximately 44,1% of the total time, while the Non-Value-Added (NVA) time is 86,3 seconds, accounting for approximately 55,9%. Most of the remaining NVA time is associated with material supply activities from the material waiting area to the production machines. The processing and finishing operations are performed continuously within the same production area, which helps minimize transportation and waiting between processes. These results indicate that the future-state production flow has been organized in a leaner manner, contributing to improved operational efficiency in the V120 department.

4.3.4. Wastes Eliminated or Reduced in the Future State VSM

The future-state VSM analysis shows that several types of waste in the production system have been eliminated or significantly reduced. Transportation waste was

greatly reduced through the establishment of a material staging area near the production line, which shortened material supply distances and reduced operator movement time. In addition, replacing the drilling process with the stamping process eliminated the transportation of semi-finished products to a separate processing area and reduced the number of intermediate handling steps in Film Gate processing. As a result, the product flow after injection molding became more continuous and the accumulation of work-in-process inventory between operations was minimized. Furthermore, the use of a stamping die and positioning fixture improved process stability, reduced dependence on operator skills, and minimized the risk of quality defects. These improvements contributed to higher production efficiency, shorter Lead Time, and a better value-added ratio throughout the production flow.

Chapter 5: Evaluation of Value Stream Improvement Effectiveness in the V120 Department

5.1. Evaluation of the layout improvement for the temporary raw material storage area at V120-2

The layout improvement solution was proposed to address the issue of raw materials being supplied from the V120-1 warehouse to the injection molding machines at V120-2. Before improvement, the material supply route was relatively long, requiring operators to travel many times per day to pick up materials, deliver them to each machine, pour the materials into the container, and return to the warehouse. This activity does not directly add value to the product but consumes time and effort and increases the Lead Time of the production flow.

After improvement, the temporary raw material storage area was arranged directly at V120-2. This area functions as a quick supply point, storing materials with high usage frequency or materials planned for short-term use. As a result, operators no longer need to travel from the main V120-1 warehouse to each machine as before, but can take materials from the temporary storage area located near the V120-2 machine group. The effectiveness of this solution is evaluated through two main indicators: material supply distance and material supply time.

a) Comparison of material supply distance before and after improvement

In terms of distance, the improvement solution directly changed the material supply route for the nine injection molding machines. Instead of taking materials from the V120-1 warehouse, operators take materials from the temporary storage area arranged near the V120-2 machine group, thereby significantly shortening the travel distance for each material supply trip.

Before improvement, the one-way distance from the V120-1 warehouse to each machine at V120-2 ranged from 64,5 m to 92,3 m. The shortest distance was to machine SE100-01 at 64,5 m, while the longest distance was to machine SE180 at 92,3 m. The total one-way distance for the nine machines was 670,4 m, corresponding to an average distance of 74,49 m/machine.

After improvement, with the material supply area located near the machines at V120-2, the one-way distance from the temporary storage area to the machines decreased to approximately 17,2 m to 24,6 m. The total one-way distance for the nine machines after improvement was 178,8 m, corresponding to an average distance of 19,87 m/machine.

Table 5.1. Comparison of Material Supply Distance Before and After Improvement

Indicator	Before improvement	After improvement	Reduction	Reduction rate
Total one-way distance for 9 machines	670,4 m	178,8 m	491,6 m	73,33%
Average one-way distance per machine	74,49 m	19,87 m	54,62 m	73,33%
Total distance per day	4.022,4 m/day	1.072,8 m/day	2.949,6 m/day	73,33%

To visualize the change in material supply distance before and after improvement, the data are presented in a column chart as shown in Figure 5.1

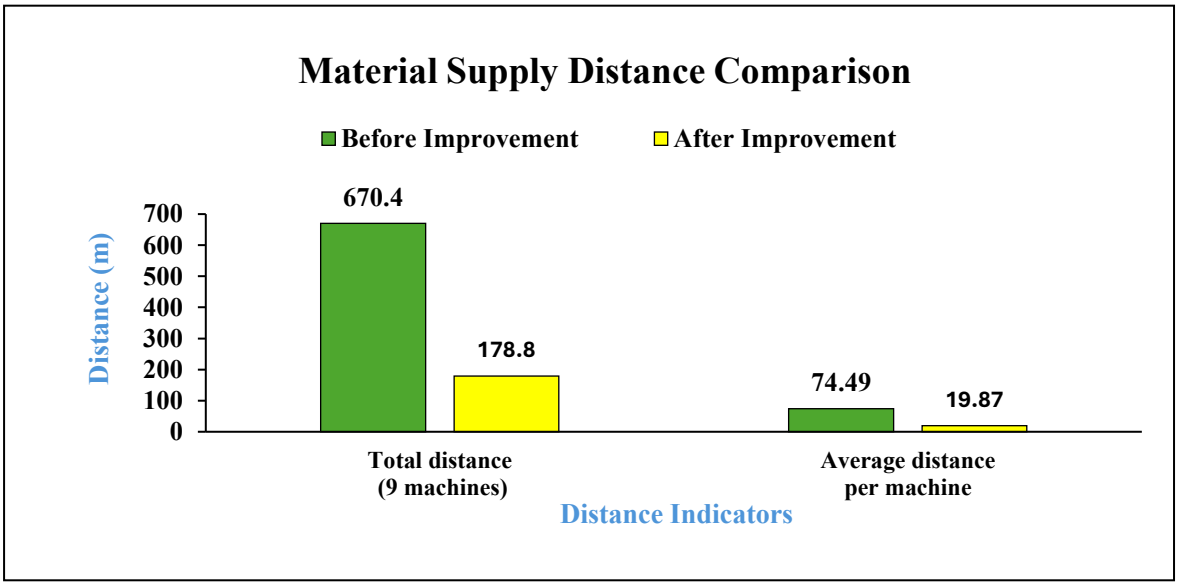


Figure 5.1. Chart Comparing Material Supply Distance Before and After Improvement

The chart shows a significant reduction in material supply distance after improvement. Moving the temporary raw material storage area closer to the V120-2 machine group reduced the travel distance by more than 70%, thereby significantly decreasing transportation waste in the material supply process. This result indicates that the new layout not only reduces the material supply distance but also enables faster and more stable material flow to the production area.

5.1.2. Comparison of Material Supply Time Before and After Improvement

In addition to distance, material supply time is also an important indicator for evaluating the effectiveness of the layout improvement solution. Material supply time includes the time required to move to the machine, take the resin, pour the resin into the container, and return. Among these components, travel time accounts for the largest proportion and is directly affected by the location of the raw material storage area.

Before improvement, the total material supply time per cycle for 9 machines was 1.991 seconds. The average material supply time per machine was 221,2 seconds/time/machine. With a frequency of 3 supply trips per day per machine, the total material supply time per day was 5.973 seconds, equivalent to 99,55 minutes/day.

After improvement, as the temporary raw material storage area was arranged near the V120-2 injection molding machines, the total material supply time per cycle for 9 machines decreased to 761,9 seconds. The average material supply time per machine decreased to 84,7 seconds/time/machine. The total material supply time per day after improvement was 2.285,7 seconds, equivalent to 38,1 minutes/day.

Table 5.2. Comparison of Material Supply Time Before and After Improvement

Indicator	Before improvement	After improvement	Reduction	Reduction rate
Total time per cycle for 9 machines	1.991 s	761,9 s	1.229,1 s	61,73%
Average time per cycle per machine	221,2 s	84,7 s	136,5 s	61,73%
Total time per day	5.973 s/day	2.285,7 s/day	3.687,3 s/day	61,73%
Converted total time per day	99,55 min/day	38,1 min/day	61,45 min/day	61,73%

To clarify the impact of the improvement solution on the material supply operation, the measured material supply time before and after improvement is presented in Figure 5.2.

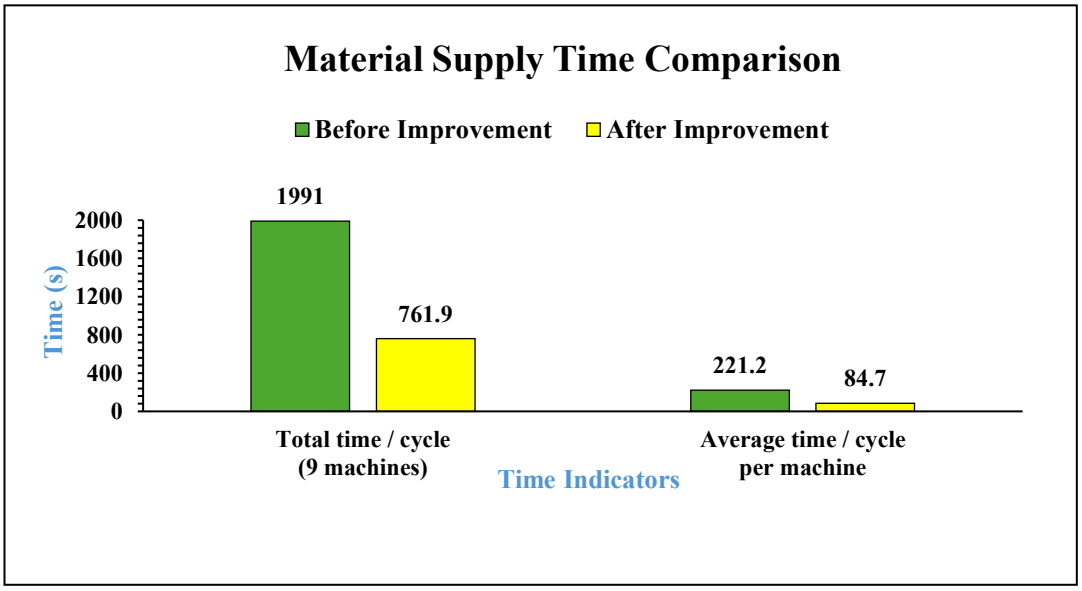


Figure 5.2. Chart comparing material supply time before and after improvement

The chart shows that the material supply time decreased significantly after the temporary raw material storage area was arranged at V120-2. This reduction mainly resulted from the shorter travel distance between the material pickup point and the injection molding machines. As a result, non-value-added time in the material supply process was reduced, and operators could respond more quickly when machines required additional materials.

From the above analysis, it can be concluded that the layout improvement of the

temporary raw material storage area at V120-2 significantly reduced transportation waste in the material supply process. After the improvement, materials were stored closer to the point of use, resulting in a substantial reduction in both material supply distance and time. This reduced non-value-added activities, improved operator convenience, minimized fatigue, and enhanced the ability to supply materials to the nine injection molding machines. Although the V120-1 warehouse still serves as the main warehouse and transportation activities have not been completely eliminated, the establishment of the temporary storage area at V120-2 has made the material supply process more centralized, proactive, and efficient, in line with Lean principles of reducing unnecessary transportation and improving material flow in production.

5.2. Evaluation of the Improvement Effectiveness of the BODY COVER 6Q4908 Processing Stage from Drilling to Stamping

Before improvement, the BODY COVER 6Q4908 processing procedure using the drilling method consisted of 10 main operation steps. These steps included direct value-added operations such as automatic machine production and drilling processing, as well as supporting activities such as visual inspection, manual gate breaking, placing products into baskets, waiting for a complete lot, and moving to the drilling area.

Table 5.3. Pre-Improvement Operation Procedure

No.	Pre-Improvement Operation Description	Time
1	Automatic machine operation	42,2 s
2	Manually break the injection gate	3,2 s
3	First visual inspection	2,2 s
4	Place into basket for the first time	2,2 s
5	When the lot is complete, move to the drilling area	180,1 s/time
6	Place the product into the drilling jig	2,2 s
7	Drilling operation	4,2 s
8	Remove the product	2,2 s
9	Second visual inspection	2,2 s
10	Place into basket for the second time	2,2 s

Note: The Cycle Time in the table is calculated based on the direct operation time per product and does not include the batch movement time to the drilling area.

If only direct operations on one product are considered, the Cycle Time before improvement is 62,8 seconds/product. In addition, the process also generates 180,1 seconds/time for moving semi-finished products to the drilling area. This time does not directly add value to the product but extends the Lead Time of the production flow.

After improvement, the stamping process is shortened to six main operation steps. Manual gate breaking, waiting for a complete lot, movement to the drilling area, placing the product into the drilling jig, and repeated inspection are eliminated or replaced by a shorter stamping process.

Table 5.4. Post-Improvement Operation Procedure

No.	Post-Improvement Operation Description	Time
1	Automatic machine operation and robot gate cutting	42 s
2	Place the product into the stamping jig	2 s
3	Stamping operation	3,1 s
4	Remove the product	2 s
5	Visual inspection	2,1 s
6	Place into basket	2 s

Compared with the original drilling method, the stamping method significantly shortens the process, thereby reducing repeated operations, lowering task complexity, and minimizing the risk of deviations during processing. The reduction rate of operation steps is calculated as follows:

Reduction rate of operation steps = 4 / 10 × 100 = 40%

Thus, the stamping method makes the BODY COVER 6Q4908 processing procedure more streamlined. Reducing the number of steps not only shortens product processing time but also reduces task complexity, decreases repeated operations for operators, and minimizes the risk of deviations during processing.

In addition, switching to the stamping method also makes the product flow more continuous. When the drilling method was used, molded products had to be collected in baskets, wait for a complete lot, and then be transferred to the drilling area. After improvement, the product can be processed by stamping directly in the post-molding flow without being separated into an independent drilling operation. This is an important improvement because it reduces interruption between the injection molding

stage and the finishing process.

5.2.1. Comparison of Operation Process and Cycle Time Before and After Improvement

Cycle Time is an important indicator for evaluating the effectiveness of the processing stage. Within the scope of the BODY COVER 6Q4908 process, the Cycle Time before improvement is determined based on the drilling process, while the Cycle Time after improvement is determined based on the stamping process.

In this study, Cycle Time refers to the direct operation time per product, while the movement time to the drilling area is considered non-value-added time generated by batch movement, mainly affecting the Lead Time of the production flow.

Table 5.5. Comparison of Cycle Time Before and After Improvement

Indicator	Before improvement: Drilling	After improvement: Stamping	Effectiveness
Cycle Time	62,8 s/product	53,2 s/product	Reduced by 9,6s /product
Main processing time	4,2 s	3,1 s	Reduced by 1,1s /product
Travel time to the drilling area	180,1 s/time	Eliminated	Reduced non-value-added time
Number of operation steps	10 steps	6 steps	Reduced by 4 steps

With an annual production volume of 43.158 products, the annual time saving is calculated as follows:

9,6 s/product x 43.158 products = 414.316,8 s/year

Converted into minutes:

414.316,8 / 60 = 6.905,3 min/year

Equivalent to:

6.905,3 / 60 = 115,1 h/year.

To clearly show the change in Cycle Time after converting the processing technology from drilling to stamping, the comparison results are presented in a column chart in Figure 5.3

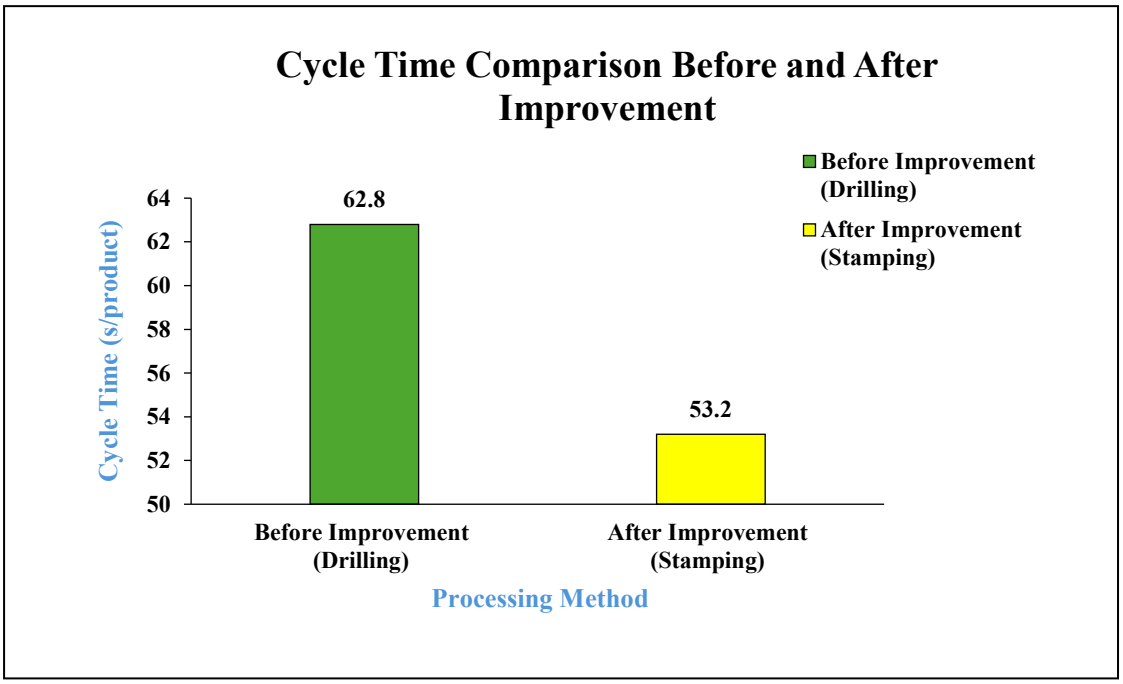


Figure 5.3. Comparison of Cycle Time Before and After Improvement

The chart shows that the Cycle Time after improvement decreased significantly compared with before improvement. The reduction of 9,6 seconds/product, equivalent to 15,29%, reflects the effectiveness of converting from the drilling method to the stamping method. With an annual production volume of 43.158 products, the direct time saving is equivalent to approximately 115,1 hours/year. In addition, the improved method also eliminates the movement time of semi-finished products to the drilling area, thereby reducing non-value-added time and improving the Lead Time of the production flow.

5.2.2. Product Quality Evaluation after Converting to the Stamping Method

Product quality after improvement was evaluated based on the ability to process the gate and Film Gate area, the post-processing appearance condition, the occurrence of burrs and scratches, and the stability of the operation during production. Before improvement, the BODY COVER 6Q4908 product was processed using the drilling method. Although this method could remove the Film Gate, it still involved several risks affecting product quality.



Figure 5.4. Current State of BODY COVER 6Q4908 Placed on the Drilling Jig

When the BODY COVER 6Q4908 product is placed face-up on the drilling jig, the product's appearance surface comes into direct contact with the jig. During processing, the operator must hold the product by hand and operate the drilling machine. Therefore, the product may shift or rub against the jig surface. This increases the risk of scratches, surface dents, machining position deviation, or burr formation at the Film Gate area. This is one of the limitations of the drilling method, especially for plastic parts with high appearance requirements such as BODY COVER 6Q4908.

In addition, during high-volume processing, the drill bit may become worn. When the drill bit is worn, its ability to cut the Film Gate consistently is reduced, which may cause the plastic film to tear, chip, or deform at the processed position. If these defects are not detected and handled in time, they may increase the non-conforming product rate.



Figure 5.5. Risk of Film Gate tearing, deformation, or burr formation at the Film Gate position during drilling

In addition, the BODY COVER 6Q4908 product has a Bearing positioning area. During the drilling process, if this area does not contact the jig stably or is subjected to uneven force during operation, burrs may occur at the positioning area. Burrs in this area may affect the assembly process, reduce part stability, and require additional inspection and rework after processing.

Based on these risks, the gate stamping method was selected to improve processing quality. After improvement, the product is placed into the stamping jig, and then the punch acts on the Film Gate position to cut off the excess plastic according to the designed profile. Compared with the drilling method, the stamping method offers more stable operation, is less dependent on drill bit wear, and reduces variation caused by manual operator handling.



Figure 5.6. Stamping Jig Used for Processing the Gate of the BODY COVER 6Q4908 Product

After stamping, the processed area becomes cleaner and more uniform, and the Film Gate area is processed consistently without any visible large burrs. The use of the stamping jig provides more secure product positioning during operation, thereby reducing cutting position deviations and minimizing the risk of defects caused by incorrect product placement.

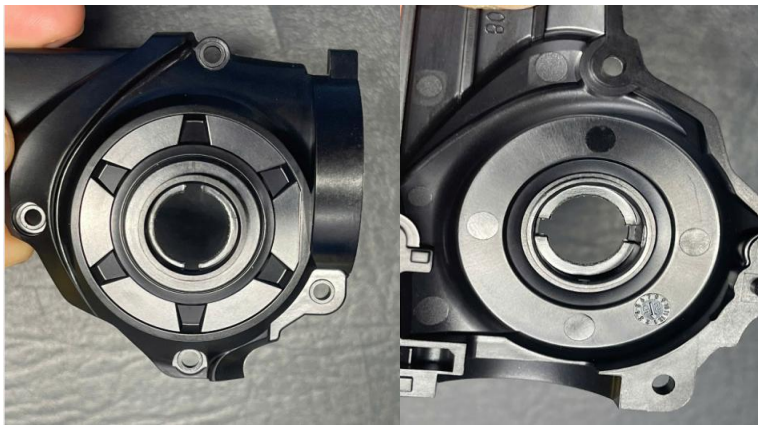


Figure 5.7. BODY COVER 6Q4908 Product after Processing by the Stamping Method

Based on the trial results, the stamping method was evaluated as satisfactory and is currently being applied at V120. This demonstrates that the stamping method meets practical requirements in terms of both operation and product quality. After converting to stamping, the process no longer depends on a drill bit, thereby reducing the risk of drill bit wear causing Film Gate tearing or incomplete cutting. In addition, the number of handling, transportation, and contact points between the product and the jig is reduced, helping to minimize surface scratches and appearance defects.

To quantify the quality improvement, this study used actual NG (non-good) data collected at the factory for the BODY COVER 6Q4908 product. During the evaluation period, the production volume of this product was 43.158 units. Before improvement, when the Film Gate was processed using the drilling method, the recorded NG rate was 1,2%. After improvement, following the conversion to the stamping method, the NG rate decreased to 0,35%.

Table 5.6. Comparison of BODY COVER 6Q4908 Product Quality Before and After Improvement

Indicator	**Before improvement: Drilling**	**After improvement: Stamping**
Production/inspection quantity	43.158 products	43.158 products
NG quantity	518 products	151 products
NG rate	1,2%	0,35%
Main defects	Burrs, scratches, Film	Reduced burrs, scratches, and

Indicator	Before improvement: Drilling	After improvement: Stamping
	Gate tearing, and Film Gate deformation	Film Gate tearing; the processed area after stamping meets requirements

From the table above, after converting from the drilling method to the stamping method, the NG quantity decreased from 518 products to 151 products, representing a reduction of 367 products/year. The NG rate decreased from 1,20% to 0,35%, equivalent to a reduction of 0,85 percentage points. In terms of relative reduction, the NG rate decreased by approximately 70,83%.

This result shows that the stamping method improves the processing quality of BODY COVER 6Q4908 compared with the drilling method. The use of the stamping jig and punch mechanism makes the Film Gate processing operation more stable, reducing dependence on operator skill and drill bit wear. As a result, common defects such as burrs, scratches, Film Gate tearing, and deformation at the Film Gate position are minimized, contributing to improved product quality and a lower NG rate during production.

5.2.3. Evaluation of Safety and Ergonomics Factors

- Ergonomic Benefits of the Layout Improvement

Table 5.7. Ergonomic Benefits of the Layout Improvement

Factor	Before improvement	After improvement	Human benefit
Material supply movement	Operators had to travel from V120-1 to V120-2 many times per day; the total distance was approximately 4,022.4 m/day.	The total distance decreased to approximately 1,072.8 m/day.	Reduced walking/pushing-pulling distance by approximately 2,949.6 m/day; reduced fatigue and non-value-added time.
Material supply time	99.55 min/day.	38.1 min/day.	Reduced by 61.45 min/day; operators have more time for

			inspection, 5S, and production support.
Operation concentration	Material supply depended heavily on walking and searching for materials.	Group A materials are placed near the point of use, with labels/QR/Kanban.	Reduced searching, reduced mistakes, and reduced stress when urgent replenishment is needed.

❖ Safety Benefits of Converting from Drilling to Stamping

Table 5.8. Safety Benefits of Converting from Drilling to Stamping

Risk before improvement	Improvement after	Safety/ergonomics value
Repeated manual gate breaking may cause hand/finger fatigue.	Robot gate cutting and the stamping process partially replace manual operations.	Reduces repetitive motion, muscle fatigue, and the risk of incorrect operation due to fatigue.
Products had to be moved to the drilling area, resulting in repeated lifting, placing, and transportation.	Stamping is arranged closer to the post-molding flow, reducing product flow separation.	Reduces handling, the risk of product dropping or scratching, and collision during movement.
Operators were directly exposed to the drilling/cutting machine, with risks related to the drill bit, plastic chips, noise, and product misalignment.	The positioning jig and stamping mechanism provide more stable operation.	Reduces dependence on individual skill and lowers risks from high-speed rotating tools.
Drilling depended on drill bit wear, which could cause burrs, scratches, or repeated inspection.	Stamping with a punch and die provides more stable positioning if properly maintained.	Reduces repeated inspection, correction pressure, and rework for operators.

5.3. Evaluation of Value Stream Improvement through Comparison of Current-State and Future-State VSMs

After implementing the two improvement solutions, including the establishment of a material waiting area at V120-2 and the conversion of the BODY COVER 6Q4908 Film Gate processing method from drilling to stamping, the production flow was simplified and the transportation of semi-finished products to the drilling area was eliminated. Based on these improvements, a Future-State Value Stream Map was developed to evaluate the effectiveness of the proposed solutions on the overall production flow.

Table 5.9. Comparison between Current-State and Future-State VSMs

Item	Current-State VSM	Future-State VSM	Improvement
Lead Time (s)	511,9	154,4	Reduced by 357,5 s
VA Time (s)	74,8	68,1	Reduced by 6,7 s
NVA Time (s)	437,1	86,3	Reduced by 350,8 s
VA Ratio (%)	14,6	44,1	Increased by 29,5 percentage points
NVA Ratio (%)	85,4	55,9	Reduced by 29,5 percentage points

Based on the current-state and future-state VSMs, three key indicators—total Lead Time, Value-Added (VA) time, and Non-Value-Added (NVA) time—were summarized to evaluate the improvement of the value stream after implementing the two proposed solutions: the establishment of a material waiting area at V120-2 and the conversion of the gate processing method from drilling to stamping. The differences between the current and future states are illustrated in the comparison chart below.

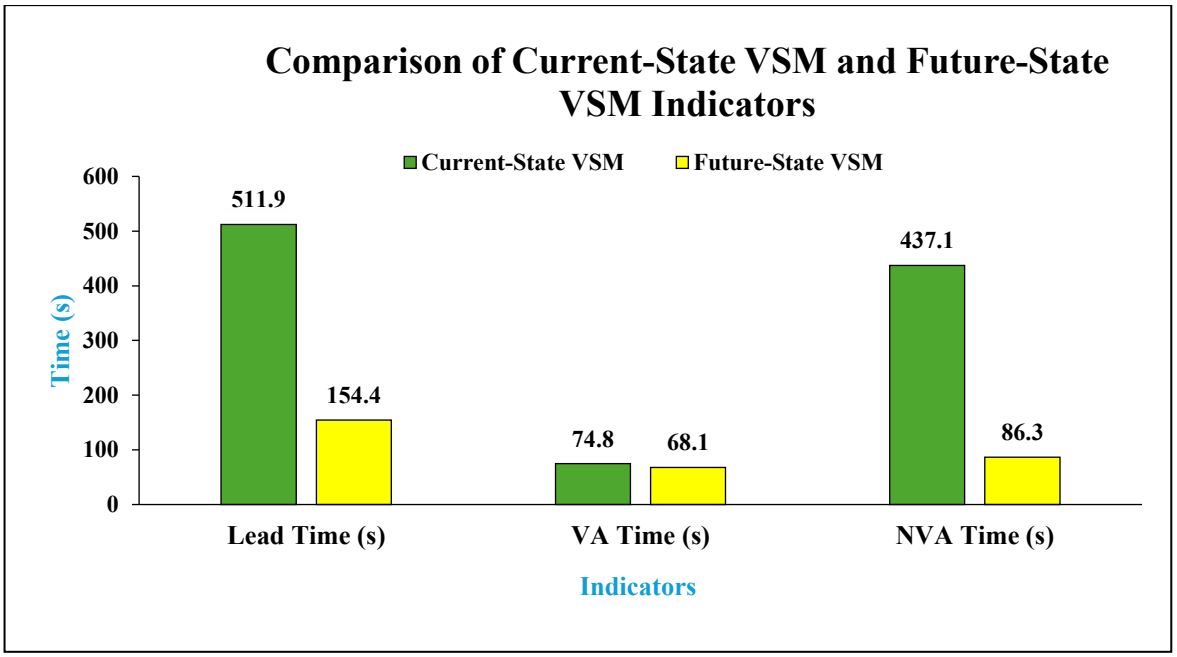


Figure 5.8. Comparison of Lead Time, VA Time, and NVA Time between Current-State and Future-State VSMs

The comparison results show that the total Lead Time decreased from 511,9 seconds to 154,4 seconds, representing a reduction of 357,5 seconds (69,84%). The Non-Value-Added (NVA) time decreased from 437,1 seconds to 86,3 seconds, corresponding to a reduction of 350,8 seconds (80,26%). Although the Value-Added (VA) time slightly decreased from 74,8 seconds to 68,1 seconds due to the change in the Film Gate processing method, the proportion of VA time within the overall value stream increased from 14,6% to 44,1%. These results indicate that the improvements were mainly achieved through the reduction of transportation activities and the elimination of unnecessary operations. As a result, the production flow in the V120 department became leaner and more efficient, contributing to shorter production lead time and improved operational performance.

5.4. Economic Evaluation of the Improvement Solutions

To comprehensively evaluate the effectiveness of this project, in addition to improvements in time, transportation distance, and value stream flow, it is also necessary to assess the economic benefits generated by the proposed solutions. Within the scope of this study, the economic benefits are derived from two main

improvement solutions: (1) establishing a satellite warehouse/temporary raw material storage area at V120-2 to reduce material supply time and related costs; and (2) converting the processing method of BODY COVER 6Q4908 from drilling to stamping to reduce processing costs, tooling costs, and costs associated with transporting products to the drilling area.

The economic evaluation is conducted through a comparison of the conditions before and after improvement, focusing on indicators such as time savings, cost savings, equivalent manpower reduction, and operational benefits. The results demonstrate that the proposed solutions are not only technically feasible but also provide significant economic value for the V120 department.

5.4.1. Economic Benefits of Establishing a Satellite Warehouse/Temporary Raw Material Storage Area at V120-2

a) Equivalent Manpower Reduction

The manpower reduction benefit in this study does not refer to a direct reduction in the number of workers. Instead, it is expressed as equivalent manpower based on the amount of labor time saved in material supply activities.

According to actual data after improvement, the average material supply time is 84.6 seconds per trip. With a total of 2.511 material supply trips per year, the total annual material supply time after improvement is calculated as follows:

$$84{,}6 \times 2.511 = 212.430{,}6 \text{ seconds/year}$$

Converted into hours:

$$212.430{,}6 / 3.600 = 59{,}01 \text{ hours/year}$$

If one worker works approximately 2.000 hours per year, the equivalent manpower after improvement is:

$$59{,}01 / 2.000 = 0{,}0295 \text{ persons/year} \approx 0{,}03 \text{ persons/year}$$

Similarly, before improvement, the average material supply time was 221,2 seconds per trip. With 2.511 trips per year, the total annual material supply time was:

$$221{,}2 \times 2.511 = 555.433{,}2 \text{ seconds/year}$$

Converted into hours:

555.433,2 / 3.600 = 154,29 hours/year

The equivalent manpower before improvement was:

154,29 / 2.000 = 0,077 persons/year ≈ 0,08 persons/year

Therefore, after establishing the temporary raw material storage area at V120-2, the equivalent manpower requirement decreased from 0,08 persons/year to 0,03 persons/year, representing a reduction of:

0,08 - 0,03 = 0,05 persons/year

Table 5.10. Equivalent Manpower Reduction

Equivalent Manpower Reduction (persons)				
		Before Improvement	After Improvement	Improvement
Effect per piece	1 (pcs)	-	-	-
Annual effect	2.511 (pcs)	0,08	0,03	0,05

The calculation results show that after establishing the satellite warehouse / temporary raw material storage area at V120-2, the equivalent manpower required for material supply activities decreased from 0,08 persons/year to 0,03 persons/year, equivalent to a reduction of 0,05 persons/year. This reduction does not mean a direct reduction in labor but reflects the labor time saved by shortening the material transportation distance and time. The saved time can be used to support other production activities such as material preparation, material inspection, machine operation support, or 5S implementation in the work area.

b) Operating Cost Saving Effect

After establishing the satellite warehouse/temporary raw material storage area at V120-2, both material supply time and transportation distance were shortened, thereby reducing the material supply cost per trip.

The operating cost saving is calculated based on the average material supply time and the company's equivalent labor cost rate. The labor cost rate is internal data

provided by the company and is used as the basis for converting labor time into operating cost.

After improvement, the average material supply time is 84,6 seconds/trip.

The material supply cost is calculated using the equivalent labor cost rate of 0,08865 USD/minute, based on internal cost data provided by the company. Therefore, the material supply cost after improvement per trip is calculated as follows:

$$84,6 / 60 \times 0,08865 = 0,125 \text{ USD/trip}$$

With a total of 2.511 material supply trips/year, the total material supply cost after improvement is:

$$0,125 \times 2.511 = 313,9 \text{ USD/year}$$

Similarly, before improvement, the average material supply time was 221,2 seconds/trip:

$$221,2 / 60 \times 0,08865 \approx 0,33 \text{ USD/trip}$$

With 2.511 material supply trips/year, the total material supply cost before improvement was:

$$0,33 \times 2.511 = 828,6 \text{ USD/year}$$

Therefore, the material supply cost decreased from 0,33 USD/trip to 0,125 USD/trip, equivalent to a saving of:

$$0,33 - 0,125 = 0,205 \text{ USD/trip}$$

The total annual cost saving is:

$$0,205 \times 2.511 = 514,7 \text{ USD/year.}$$

Table 5.11. Comparison of Material Supply Cost Before and After Improvement

Cost Saving Effect (USD)				
		Before Improvement	After Improvement	Improvement
Effect per piece	1 (pcs)	0,33	0,125	0,205
Annual effect	2.511 (pcs)	828,6	313,9	514,7

The results show that establishing the satellite warehouse/temporary raw material storage area at V120-2 helps shorten material supply time, thereby reducing the equivalent labor cost for material supply activities. With 2.511 material supply trips per year, the total cost saving is approximately 514,76 USD/year, indicating that the layout improvement can generate economic benefits by reducing non-value-added activities during operation.

5.4.2. Economic Benefits of Converting the Processing Technology from Drilling to Stamping

For the solution of converting the BODY COVER 6Q4908 processing technology from drilling to stamping, the economic benefits are evaluated through three main groups: profit from reduced process cost, profit from reduced tooling cost, and profit from eliminating movement time to the drilling area. These indicators directly reflect the cost savings achieved after changing the processing method.

a) Profit from reduced process cost

The process cost before and after improvement is determined based on the Cycle Time of each processing method and the company's equivalent labor cost rate. The equivalent labor cost rate used is 0,08865 USD/minute, based on internal cost data provided by the company.

Before improvement, the BODY COVER 6Q4908 product was processed using the drilling method, with a Cycle Time of 62,8 seconds/product.

The process cost before improvement is calculated as follows:

$$62,8 / 60 \times 0,08865 = 0,0928 \text{ USD/product}$$

After improvement, the product was changed to the stamping method, with a Cycle Time of 53,2 seconds/product.

The process cost after improvement is calculated as follows:

53,2 / 60 x 0,08865 = 0,0786 USD/product

Therefore, the process cost saving per product is:

0,0928 - 0,0786 = 0,0142 USD/product

With an annual production volume of 43.158 products, the total process cost before improvement is:

0,0928 x 43.158 = 4.004,77 USD/year

The total process cost after improvement is:

0,0786 x 43.158 = 3.392,61 USD/year

Thus, the annual process cost saving is calculated as follows:

4.004,77 - 3.392,61 = 612,16 USD/year.

Table 5.12. Comparison of Process Cost Before and After Improvement

Cost Saving Effect (USD)				
		Before Improvement	After Improvement	Improvement
Effect per piece	1 (pcs)	0,0928	0,0786	0,0142
Annual effect	43.158 (pcs)	4.004,77	3.392,61	612,16

The results show that converting from the drilling method to the stamping method reduces the process cost from 0,0928 USD/product to 0,0786 USD/product. With an annual production volume of 43.158 products, the saving is approximately 612,16 USD/year. This is a direct cost saving achieved by shortening the Cycle Time and simplifying the processing procedure.

b) Profit from Reduced Tooling Cost

Tooling cost is determined based on the unit cost of tools and the annual usage quantity according to the company's actual data. Before improvement, the drilling process used drill bits with a unit cost of 86,96 USD/piece and an annual consumption

of 2 pieces/year, corresponding to a cost of 173,92 USD/year. After improvement, the stamping process uses punches and dies with a cost of 12 USD/set and a replacement quantity of 4 sets/year, corresponding to a cost of 48 USD/year. Therefore, converting from the drilling method to the stamping method helps reduce tooling cost as follows:

173,92 - 48 = 125,92 USD/year.

Table 5.13. Tooling Cost Saving After Converting from Drilling to Stamping

Tool	Cost (USD)	Quantity/year	Amount	Profit
Drill bit	86,96	2	17,92	125,92
Punch and die	12	4	48	

The results show that the stamping method has a lower tooling cost than the drilling method. This is because the milling cutter is more expensive and tends to wear out during high-volume processing, while the punch and die have lower costs and are more suitable for repeated stamping operations. Therefore, switching to stamping not only stabilizes the operation but also helps reduce tooling costs during production.

c) Profit from Eliminating Movement Time to the Drilling Area

Before improvement, after the product was molded, semi-finished products had to be collected and moved to the drilling area for further Film Gate processing. This movement activity did not directly add value to the product but still generated additional time, labor, and operating cost. Therefore, it was considered a form of transportation waste in the production flow.

Cost Saving Effect (USD)				
		Before Improvement	After Improvement	Improvement
Effect per piece	1 (pcs)	0,222	0	0,222
Annual effect	837 (pcs)	186	0	186

According to the calculation results, the cost associated with moving products to

the drilling area before improvement was 0,222 USD/trip. After converting to the stamping method, the drilling operation was replaced, and products no longer needed to be moved to a separate drilling area. Therefore, this cost was eliminated. The saving per trip is calculated as follows:

$$0{,}222 - 0 = 0{,}222 \text{ USD/trip}$$

With 837 movement trips used for the effectiveness calculation, the profit from eliminating movement time to the drilling area is calculated as follows:

$$0{,}222 \times 837 = 185.814 \text{ USD/year} \approx 186 \text{ USD/year}$$

Thus, eliminating the movement step to the drilling area saves approximately 186 USD/year. In addition to the monetary saving, this improvement also makes the product flow more continuous, reduces batch waiting time, decreases transportation operations, and minimizes interruption between the injection molding stage and the post-molding processing stage.

Total profit from converting from drilling to stamping

- Profit from reduced process cost: 612,16 USD/year
- Profit from reduced tooling cost: 125,92 USD/year
- Profit from eliminating movement time to the drilling area: 186 USD/year

The total annual profit is calculated as follows:

$$612{,}16 + 125{,}92 + 186 = 924{,}08 \text{ USD/year.}$$

5.4.3. Summary of the Economic Benefits of the Two Improvement Solutions

The economic benefits of the project are summarized from two main improvement solutions: establishing a satellite warehouse/temporary raw material storage area at V120-2 and converting the BODY COVER 6Q4908 processing technology from drilling to stamping. The satellite warehouse solution reduces material supply costs by shortening the raw material transportation distance and time. The conversion from drilling to stamping reduces processing costs, tooling costs, and eliminates the cost of moving semi-finished products to the drilling area.

Table 5.14. Specifically summarizes the savings of each improvement solution

Improvement Solution	Saving Item	Before Improvement	After Improvement	Saving
Establishing a satellite warehouse / temporary raw material storage area at V120-2	Material supply operation time	9.257,22 min/year	3.540,51 min/year	5.716,71 min/year
	Converted operation time	154,29 h/year	59,01 h/year	95,28 h/year
	Equivalent manpower	0,08 persons/year	0,03 persons/year	0,05 persons/year
	Material supply cost	828,6 USD/year	313,9 USD/year	514,76 USD/year
Conversion from drilling to stamping	Process cost	4.004,77 USD/year	3.392,61 USD/year	612,16 USD/year
	Tooling cost	173,92 USD/year	48 USD/year	125,92 USD/year
	Cost of movement to the drilling area	186 USD/year	0 USD/year	186 USD/year

When combining the two solutions, the achieved effectiveness is reflected not only in annual cost savings but also in improved production flow, reduced non-value-added activities, and enhanced operational efficiency in the V120 department.

5.5. Limitations of the Project and Expansion Potential

Although the improvement solutions have brought positive results in the material supply operation and the BODY COVER 6Q4908 processing stage, the project still has several limitations in terms of research scope, data collection period, and applicability to other areas or part numbers. Therefore, this section presents the existing limitations, expansion potential, and future improvement directions to maintain the effectiveness after implementation.

5.5.1. Limitations of the Study

The first limitation is related to the research scope. The project mainly focuses on the material supply route from V120-1 to the nine injection molding machines at V120-2 and the post-molding processing stage of the BODY COVER 6Q4908 product. Therefore, the improvement results properly reflect the selected area and part number, but they cannot fully represent the entire V120 department or all other plastic products.

The second limitation is that the data were collected within a specific period, so they may not fully reflect fluctuations in the production plan. In practice, production volume, material supply frequency, material structure, and machine operating schedules may change over time, which may also affect the effectiveness of the temporary raw material storage area and the stamping method.

The third limitation is that product quality after improvement still needs to be monitored over a longer period. The trial results show that the stamping method meets the requirements for appearance and processing position; however, more NG data over multiple production periods are needed to evaluate the defect reduction level and the stability of the punch and die more clearly.

The fourth limitation is that the economic analysis mainly focuses on direct savings, such as material supply cost, process cost, tooling cost, and movement cost. Other factors such as initial investment cost, equipment maintenance, jig service life, inventory management cost at the temporary storage area, and payback period have not been analyzed in depth.

The fifth limitation is that the project has not deeply analyzed supporting factors such as occupational safety, operator fatigue, stamping machine OEE, punch/die service life, and the impact of inventory at the temporary raw material storage area on production layout. These are important factors if the solution is to be expanded into a long-term operating standard.

5.5.2. Applicability to Other Part Numbers

The improvement solutions in this project can potentially be expanded to other part numbers, but specific application conditions must be evaluated before implementation.

For the temporary raw material storage area at V120-2, the expansion potential is relatively high. The principle of this solution is to move frequently used materials closer to the point of use, thereby reducing material supply distance and time. This principle can be applied to other machines or areas if the following conditions are met:

- The production area is located far from the main raw material warehouse.
- There are materials with high usage frequency or stable production demand.
- There is sufficient empty space to arrange pallets or temporary material racks.

- Materials can be controlled using identification labels, FIFO, and 5S.
- The material arrangement does not obstruct walkways, operation areas, or production safety.

However, when expanding this solution, not all materials should be moved to the temporary storage area. ABC analysis should continue to be used to select priority materials. Group A materials should be arranged in fixed or semi-fixed positions near the machines; Group B materials can be arranged flexibly according to the production plan; and Group C materials should remain in the main warehouse if their usage frequency is low.

For the technology conversion from drilling to stamping, applicability to other part numbers depends more on the technical characteristics of each product. Not every product can be converted to stamping. Another part number should only be considered for stamping if it meets the following conditions:

- The gate and Film Gate position are suitable for cutting by stamping force.
- The Film Gate is not too thick and does not cause cracking or deformation during stamping.
- The punch, die, and positioning jig can be designed accurately.
- The product has sufficient rigidity and suitable structure to withstand stamping force.
- Production volume is stable enough to justify investment in the jig, punch, and die.
- Stamping machines and operators have sufficient capacity to meet production demand.
- The product after stamping meets appearance, dimensional, and assembly requirements.

For BODY or BODY COVER part numbers with structures similar to BODY COVER 6Q4908, the stamping method can be considered for expansion after sample testing. An evaluation table should be prepared for each part number based on criteria such as gate size, gate length after cutting, Film Gate thickness, appearance requirements, production volume, current drilling time, and feasibility of stamping jig design.

Thus, the temporary raw material storage solution has broader expansion potential because it mainly relates to layout and material management. Meanwhile, the stamping solution has selective expansion potential, depending on the technical characteristics of each part number and equipment conditions.

5.5.3. Future Improvement Directions

In the future, to maintain and expand the improvement effectiveness, the V120 department may continue implementing the following improvement directions.

First, standardize the temporary raw material storage area at V120-2. After arranging the area, clear operating rules should be established, including the list of materials allowed to be stored, maximum and minimum inventory levels, FIFO rules, labeling methods, material replenishment timing, and daily inspection responsibilities. Standardization helps prevent the temporary storage area from becoming an uncontrolled storage space or obstructing the production layout.

Second, apply Kanban or material supply cards for the temporary raw material storage area. When materials at V120-2 decrease to the minimum level, Kanban cards can be used to signal replenishment demand from the main warehouse. This helps make material supply more proactive, prevents unexpected material shortages, and limits excessive inventory in the production area.

Third, continue monitoring post-improvement data. The indicators to be tracked include material supply time, number of material supply trips per day, number of machine waiting cases due to material shortage, inventory level at the temporary storage area, wrong material supply cases, NG quantity after stamping, and punch/die condition. Periodic monitoring helps evaluate whether the solution maintains stable effectiveness.

Fourth, expand VSM analysis to other product flows. After the solution has proven effective for BODY COVER 6Q4908 and the V120-2 area, the department can continue selecting high-volume part numbers, products with many post-molding operations, or routes with long transportation distances to build VSM and propose similar improvements.

Fifth, supplement the economic analysis with actual cost data. When sufficient data on labor cost, stamping machine cost, jig cost, punch/die cost, NG cost, and internal transportation cost are available, the department can accurately calculate total economic benefits, payback period, and annual savings. This will provide an important basis for expanding the improvement throughout the department.

Sixth, consider applying digital tools in material management. For example, QR codes or electronic tracking boards can be used to control materials at the temporary storage area, record inventory levels, replenishment time, and material supply history. This helps make data more transparent and supports faster decision-making.

In general, future improvement directions should focus on two objectives: maintaining the achieved effectiveness and expanding improvements in a controlled manner. Improvement should not stop at one layout rearrangement or one technology conversion, but should be maintained as a continuous improvement cycle in the spirit of Lean.

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