Reducing Process Waste for Enhanced Efficiency: A tobacco industry case study

Jannette Pérez Barbosa, MS[1]; Andres R. Loran Butron [2]; Sebastián Ortiz Delgado [3]; Dana García Vargas [4]
[1]Universidad Ana. Méndez, Gurabo Campus, Puerto Rico, jperez222@uagm.edu
[2]Universidad Ana. Méndez, Gurabo Campus, Puerto Rico, lorana1@uagm.edu
[3]Universidad Ana. Méndez, Gurabo Campus, Puerto Rico, sortiz364@email.uagm.edu
[4]Universidad Ana. Méndez, Gurabo Campus, Puerto Rico, dgarcia200@email.uagm.edu

***Abstract*– The Cigarette Company (CI), a leading manufacturer with over 50 years of experience, specializes in machine-made cigars and is recognized for its commitment to quality and sustainability. This study addresses inefficiencies in waste management and production processes within the BasicA cigar production line, which accounts for 85% of the company's output. Key issues include unstandardized waste documentation, inconsistent data collection, and operational inefficiencies. By implementing standardized operating procedures (SOPs), digital waste logging systems, and enhanced material handling practices, the project achieved a 15% reduction in tobacco waste and a 5% improvement in operator utilization.**

Keywords—waste reduction, Lean Six Sigma, sustainability, tobacco industry, industrial engineering.

I. Introduction

The Cigarette Company (CI), a cigar manufacturer, is committed to producing high-quality cigars, and maintaining environmental sustainability. Tobacco, one of the company's most expensive raw materials, generates significant waste during production, especially in the BasicA cigar line, which accounts 85% of production. The monthly waste is estimated at 2%. Recent operational evaluations identified critical inefficiencies in waste documentation, material handling, and machine performance, compounded by unstandardized processes and limited data accuracy. These issues have negatively impacted productivity and the company's adherence to its sustainability goals, driving the need for a systematic approach to improvement.

This paper will apply the DMAIC methodology to improve a manufacturing process. DMAIC (Define, Measure, Analyze, Improve, and Control) is a "structured, data-driven approach designed to enhance process efficiency, eliminate waste, and standardize operations" [1]. The authors from this research also remark that some key factors such as communication, training, tying continuous improvement to company goals and project prioritization and tools are part of the factors for successful lean six sigma implementation [1]. Another key principle of lean six sigma is the identification of value. A waste walk was used to identify and compute the percentage of time used in value-added and non-value-added activities. A large percentage of non-value activities that can increase process time and result in losses in productivity. An initiative in Indonesia focused on using the waste analysis to reduce cigarette paper waste. As part of their efforts, they modeled productive activities with a Value Stream map, and corrective actions included layout changes to reduce walking distances and frequency [2].

The research objectives are: achieve a waste reduction of 15% and increase personnel utilization by 5%. Failure to address these issues will lead to increasing material costs, continued inefficiencies in production, and difficulties in maintaining the quality standards of our high-demand products. Study focuses on improving waste documentation processes, optimizing operator utilization, and reducing machine-related inefficiencies.

Key areas of intervention include:

1. Standardizing Waste Collection and Documentation - Implementation of digital logging systems and Standard Operating Procedures (SOPs) for real-time waste tracking and analysis.
2. Optimizing Material Handling - Mulch vacuum systems and utility cage carts will be introduced to streamline workflows and reduce delays caused by inefficient waste transport.
3. Enhancing Operator Training - Conducting training programs to ensure consistency in waste handling and machine utilization across shifts.
4. Analyzing Machine Performance - Addressing high waste generation in specific production machines, to identify root causes and implementing corrective actions.

To establish the operation baseline and estimate standard time and capacity, Man-Machine diagrams were utilized; these are part of the work measurement tools applied in this project [3] and can be used to evaluate if the operation can manage one or more machines. The area layout is shown in Fig. 1 and is designed to have an operator manage three machines simultaneously. Each machine produces forty-five cigars per minute, and the plant maintains a buffer of 1 day's production. The cigar waste is measured by operators after each bobbin change.

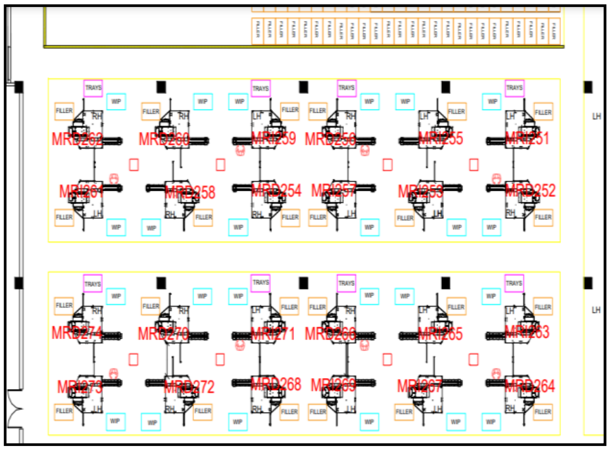

Fig. 1. BasicA Current Layout

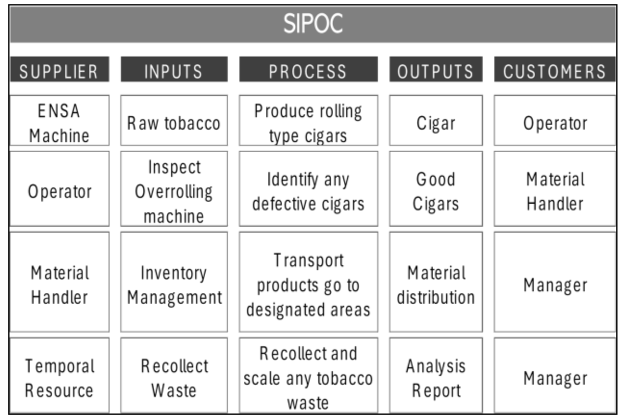

Fig. 3. SIPOC diagram for CI

In Fig. 2, the Critical to Quality (CTQ) diagram serves as a foundation establishing the critical to quality factors and desired goals. Translating the aspirations to quantitative results [4] facilitated establishing deliverables for tobacco waste during production:

1. Standardizing processes across six waste areas.
2. Optimize material transport to 20 minutes.
3. Increase waste measurement accuracy by 25%.

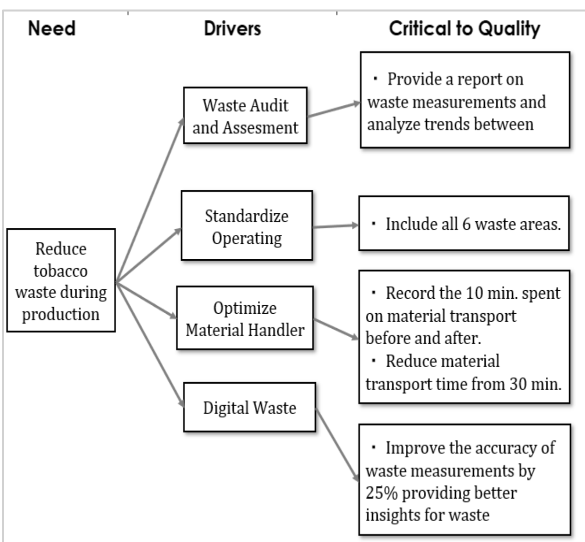

Fig. 2. Critical to Quality diagram for CI International

A SIPOC diagram is shown in Fig. 3. This tool facilitates a high-level visualization of the production process and its most critical inputs and outputs and can be used in varied manufacturing applications. An application from literature includes using a SIPOC diagram to recognize all steps, stakeholders and equipment in the tasks for part repair [5].

The current outputs include both good and bad products, making waste reduction an important element to consider, not just because of the yield, but also to the management of wasted materials and final products.

II. HISTORICAL DATA ANALYSIS

The historical data analysis evaluated the current state of waste management and production inefficiencies across Machines 275, 276, and 278. Fig. 4 illustrates the monthly waste in ASN machines used in BasicA production, highlighting the monthly variations in waste. The inconsistencies observed in waste levels can be attributed to machine inefficiencies and manual errors during production. Monthly waste levels averaged around 2% of total production but showed inconsistencies due to machine inefficiencies and manual errors. Higher production days correlate with increased waste, suggesting that waste generation scales with production volume.

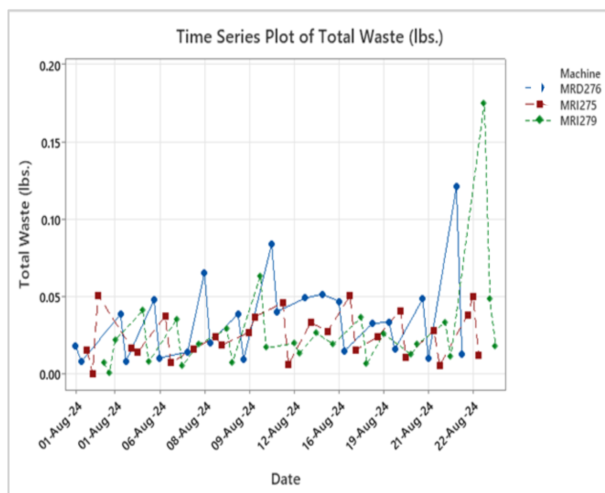

Fig. 4. Basic Waste Collection Data Time Series

The process capability was evaluated in Fig. 5 and computed the percentage of the process outside of specifications. Since both potential and actual capability (Cp and Cpk= 0.58) indexes are below the recommended 1.33 target [6], the current waste management process does not meet specification limits. The estimation of the parts per million (PPM) for the within (Cp) capability is High; close to 40,000 PPM resulting in a significant portion of waste produced.

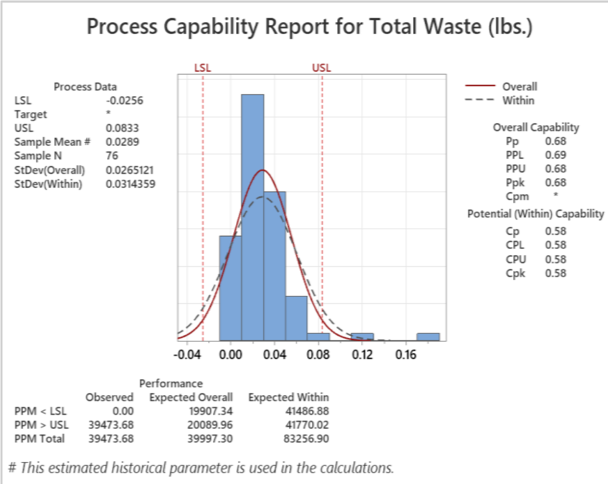

Fig. 5. Process Capability Report for Total Waste

Since there was no defect classification strategy (as shown in Fig. 4) one of the first initiatives from the team was to stratify the waste data with an experimental waste collection plan. This plan established several categories: initial cuts, stuck cuts, QC removals and machine rejects. The increase of waste collected after this plan is shown on Fig. 6. This reveals frequent and more substantial peaks, with waste values reaching up to 3 lb. on certain days. The difference the result of operators and material handlers now collecting waste with a consistent system for distinguishing different types of waste. The previous general collection plan led to misreporting and mixing of waste, resulting in an average waste of 0.017 lb.

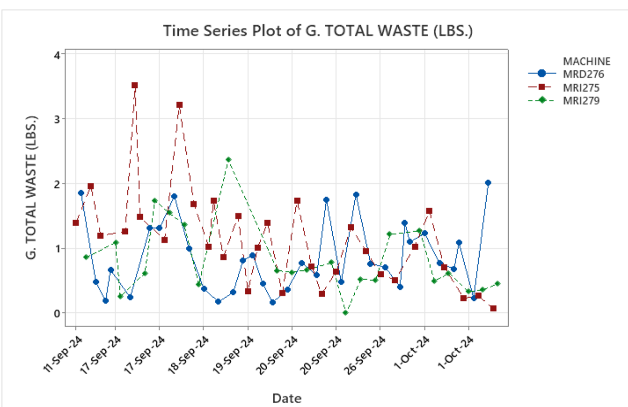

Fig. 6. BasicA Cigar Waste Collection Data Experimental Design

It was relevant to measure if the production shifts had significantly different waste percentages. Table 1. shows the variations in waste documentation between shifts and further emphasizes the need for improved tracking systems.

Table 1. BasicA % Difference of Cigar waste by shift

All Waste value from bobbins LBS				
Shift	Sept23-Aug24	Sept24-Oct24	% increase	Difference
First shift	0.577085	2.27079	75%	1.693705
Second S	0.349688	2.26095	85%	1.911262

An analysis of variance (ANOVA) is shown in Figure 7 to evaluate waste variability by machine. It revealed no statistically significant difference in waste percentages across machines; thus, the identified improvement measures could be applied uniformly across all machines.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
MACHINE	2	0.04999	0.02500	2.11	0.129
Error	68	0.80443	0.01183		
Total	70	0.85442			

Fig. 7. Analysis of Variance of ASN Machines

A test to compare of average waste collection changed when transitioning from the previous (2023) manual estimation method (μ_1) and the new (2024) experimental data collection method ($\mu 2$) showed significant statistical differences since the p-value =0; meaning the alternative hypothesis of equal means is rejected. The new method captured a more accurate representation of total waste, (Fig. 6).

Method

μ_1: population mean of Sample 1
μ_2: population mean of Sample 2
Difference: μ_1 - μ_2

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Sample 1	88	0.0348	0.0250	0.0027
Sample 2	88	0.517	0.404	0.043

Estimation for Difference

Difference	95% CI for Difference
-0.4822	(-0.5680, -0.3964)

Test

Null hypothesis H_0: $\mu_1 - \mu_2 = 0$
Alternative hypothesis H_1: $\mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-11.18	87	0.000

Fig. 8. Two-sample T-test for waste detection baseline vs. recommendations

After identifying an opportunity in more detailed collection methods, we identified the value added and non-value-added operations in the manufacturing process and established the current standard time.

A Man-Machine study was conducted to determine the standard time of the Operator and Material Handler's tasks performed manually, such as transporting primary materials, preparing stations, collecting, and transporting cigars. This is shown in Table 4, with the utilization for operators at 90% due to an unstandardized way to measure waste, leading to the operator wasting time documenting said waste. Waste contributed to reduced production efficiency, with operators spending an average of 10.5 minutes per 2-hour shift on waste documentation and collection. The issue of waste now includes not just the missing collection areas, but also the measurement method.

Table 2. Man-machine of the first shift Operator total time.

Operator first shift		
Sum Time	Time	Actividad
31.8	31.8	Collect cigar
76.9	45.1	idle
125.9	49	clean machine
224.9	99	Collect cigar
284.9	60	idle
429.9	145	Collect cigar
437.9	8	idle
493.9	56	Collect cigar
503.9	10	idle
580.9	77	Collect cigar
705.9	125	bobbin change
735.9	30	*other operator had to take over collection

In contrast, the second shift operates with only about 25% of the first shift headcount and focuses solely on ASN and packing machines as shown in Table 3. The discrepancy in personnel allocation between shifts highlights the need for a more balanced and efficient staffing strategy to optimize production and minimize waste.

Table 3. Man-machine of the second shift Operator total time.

operator second shift		
Sum Time	Time	Activity
22.69	22.69	Pick up Cigars in M-2
34.46	11.77	Stoped Machine
50.80	16.34	Pick up Cigars in M-1
72	21.20	SIC Documentation
103.01	31.01	Search for bobbin
150.36	47.35	Pick up Cigars in M-2
156.09	5.73	Pick up Cigars in M-1
204.46	48.37	Operator Idle
234.1	29.64	Pick up Cigars in M-1
260.53	26.43	SIC Documentation
285.07	24.54	Operator Idle
294.48	9.41	Pick up Cigars in M-3

In Fig. 9, all three of our machines (A is X275, B is MRD276, and C is X 279) are above 90% yield, which indicates that the variability between machines could be low enough to assume that improvements will be applicable across all machines. This is also corroborated by the ANOVA results on Fig. 7.

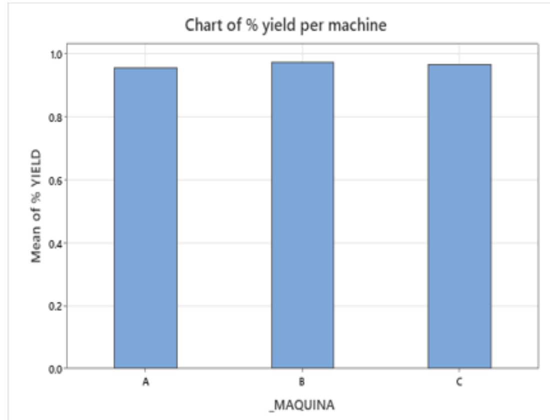

Fig. 9. Chart of % yield for machines A, B & C

III. ROOT CAUSE ANALYSIS

The root cause analysis aimed to reveal the primary drivers of waste management inefficiencies in the weighting process, which is unstandardized. In Fig. 10 all potential causes are mentioned in the Fishbone diagram, in one of the six sources of variation (the six M's). Using the supporting information presented previously, three significant root causes were identified:

1. Lacking waste counting system.
2. Untracked disposal of waste
3. Inconsistent logging and measurement accuracy

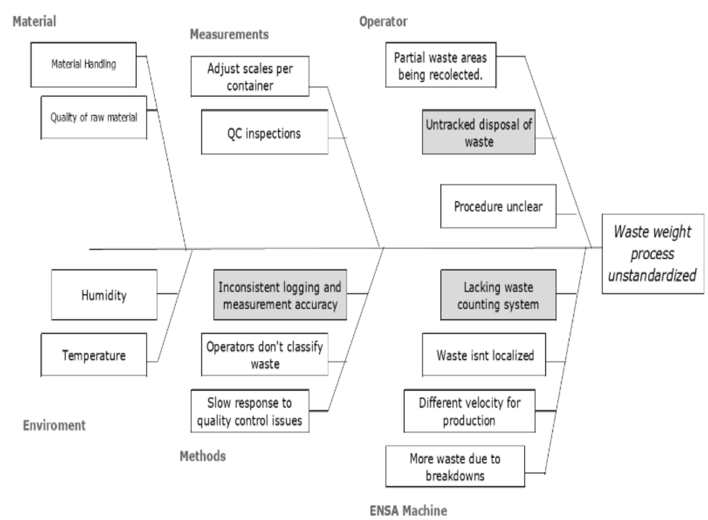

Fig. 10. Waste weight process unstandardized Ishikawa diagram.

To further drill down on the root causes and facilitate the development of alternatives these potential root causes were also analyzed using the 5Why tool.

- Subproblem 1 in Fig. 11 shows that the root cause is the standardized equipment underutilization, leaving room for operator-dependent errors and misclassifications.

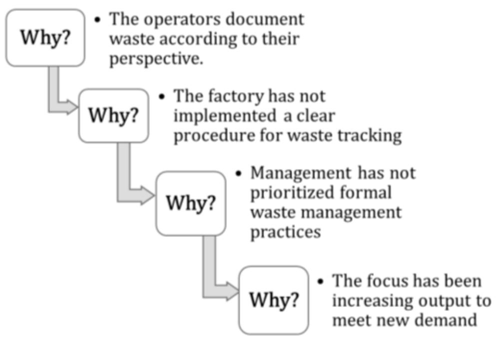

Fig. 11. Subproblem 1: Lacking waste counting system

- Subproblem 2 Fig. 12 shows operators fail to record waste from certain areas because newer waste-generating zones are not identified.

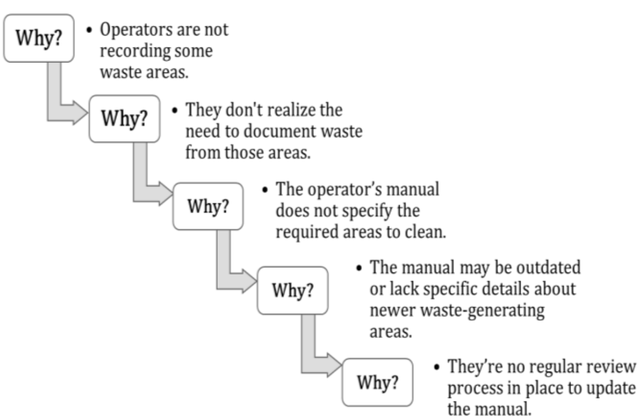

Fig. 12. Subproblem 2: Untracked disposal of waste.

- Subproblem 3 (Fig. 13) shows operators document waste based on personal perspectives due to the absence of a formalized waste tracking procedure. This results in inconsistent data collection and untracked waste from critical areas.

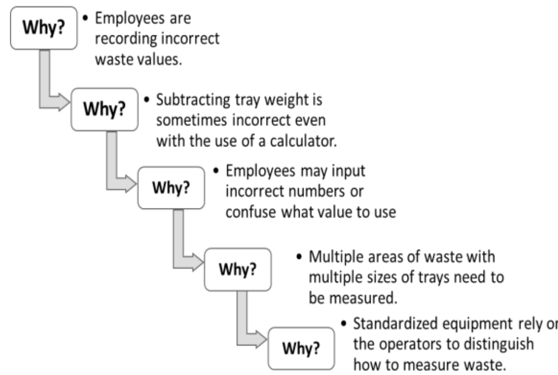

Fig. 13. Subproblem 3: Inconsistent logging and measurement accuracy

IV. Evaluation of Alternatives

Solutions to address equipment downtime, no standardization, communication between shifts, and equipment waste subproblems were evaluated using a weighted decision matrix based on technical and economic feasibility, effectiveness, and potential drawbacks. This method has been applied to several industrial and service applications, for example in a flower shop, that similarly used a weighted decision matrix to find alternatives that reduced waste and service time [7].

Table 4 outlines alternatives for improving BasicA production:

- Operator Training and SOPs: A low-cost, effective solution that emphasizes standardized waste management and adaptable practices with future potential of adapting other more comprehensive approaches. These proved successful in the implementation of a Procedural Waste Index that is integrated into procedures to reduce documentation complexity, improve communication and standardize operations [8].
- Enhanced Communication Systems: Tools to streamline shift-to-shift communication, minimizing delays and improving coordination.
- Upgraded Maintenance Protocols: Preventive maintenance schedules and monitoring systems to reduce downtime, though requiring a higher initial investment.
- Equipment and tools such as utility carts and vacuum machines to facilitate waste collection.

Table 4. Decision Analysis for BasicA

Sub-Problem	Alternative	Technical Feasibility (weight: 3)	Economic Feasibility (weight: 3)	Unforeseen drawbacks (weight: 1)	Effectiveness (weight: 2)
Equipment Downtime	1. Automated Waste Data Collection System	6	6	3	10
	2. Give operator control over machine speed	6	6	2	10
	3. Feasibility study to run machines faster	6	3	0	2
No Standardization	4. Color Coded Bins	9	9	4	2
	5. Integrated Documentation Scale	3	3	1	8
	6. SOP for waste collection	6	9	2	10
Non-Value Added Activities	7. Schedule Recollection Times	3	3	2	2
	8. Material Handler Re-Training	9	9	3	8
Communication Between Shifts	9. Shift Change Checklist	3	3	2	10
	10. Re-training of Preparation Area	12	6	5	2
	11. Orientation for awareness of machine "red, yellow, green" indicators	6	6	5	10
Equipment Waste	12. Utility Cage Cart	6	3	1	2
	13. Cut Acrylic for Buffer	3	3	1	8
	14. Mulch Vacuum	12	15	5	10
Difference Between Shifts	15. Re-evaluation of Personnel Hiring Formula	15	15	3	6
	Total Weight Score	105	99	39	100

The weighted decision matrix highlighted operator training and SOP implementation as the most cost-effective option with immediate benefits. Enhanced communication systems offered valuable support for efficiency, while maintenance upgrades showed long-term potential despite higher costs and extended timelines. The implementation of these alternatives will be conducted in a coordinated and systematic manner, ensuring alignment with enterprise elements, including work processes, resources, information flow, and decision-making.

V. Results and Conclusions

The following section will show the improvements with the selected alternatives. With the Utility Cart, the workflow redesign significantly enhanced efficiency, with task durations reduced due to optimized layouts and streamlined processes. In Fig. 14, we see the proposed layout for BasicA. The results of these initiatives were substantial. Waste inside machines was reduced by 85%, far exceeding the target of 20%. Service times improved by 9.9%, surpassing the initial goal of 5%.

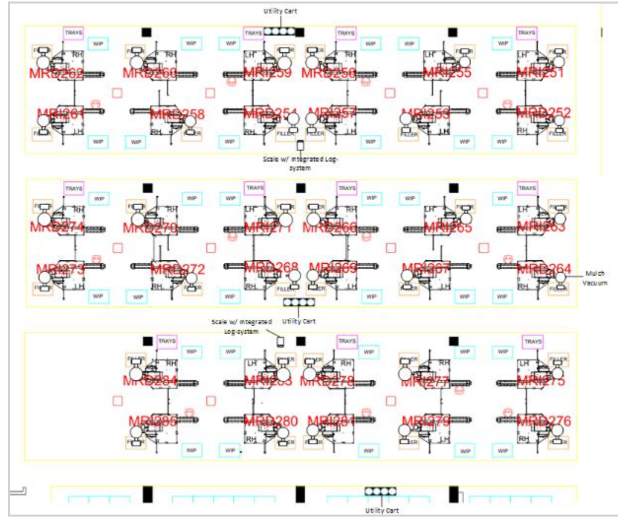

Fig. 14. Proposed Layout for BasicA Production Area

Utility cage carts minimized material transport time, reducing travel distance by 83% and enabling quicker material availability as seen in Fig. 15 (Before) and 16 (After). A new Integrated Waste Documentation System using digital technology was proposed, resulting in a significant improvement in accuracy and waste tracking. ROI was calculated at 1176%, with a payback period of 0.08 years

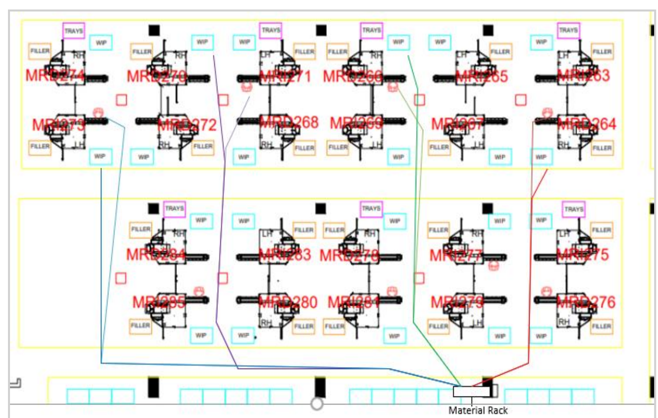

Fig. 15. Before Spaghetti diagram of Operators at the Production line searching for material

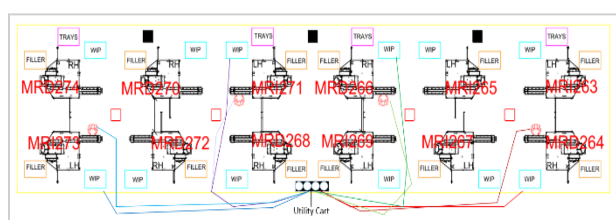

Fig. 16. Spaghetti diagram of Operators at Production line after Utility Cart implementation

A shift change checklist with the unified model language to facilitate integration (Fig. 17) reduced material-related delays by 90%, improving material availability from 36% to 64%. The checklist was implemented within one week and achieved an ROI of 2562%.

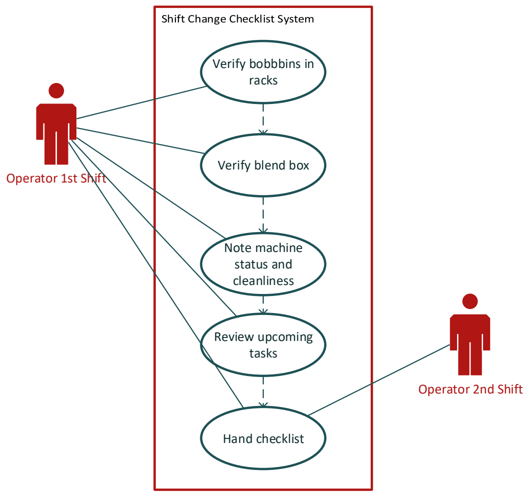

Fig. 17. Unified Modeling Language Use Case for Shift Change Checklist Use

Fig. 18 shows the Pareto chart computing the percentage of waste per Type. The metal filter and trimming residual is the area that creates more waste covering 40% of the overall waste created by the ASN machines. The implementation of color-coded bins standardized waste segregation resulted in a 20,824% increase in detected waste and a significant reduction in untracked material.

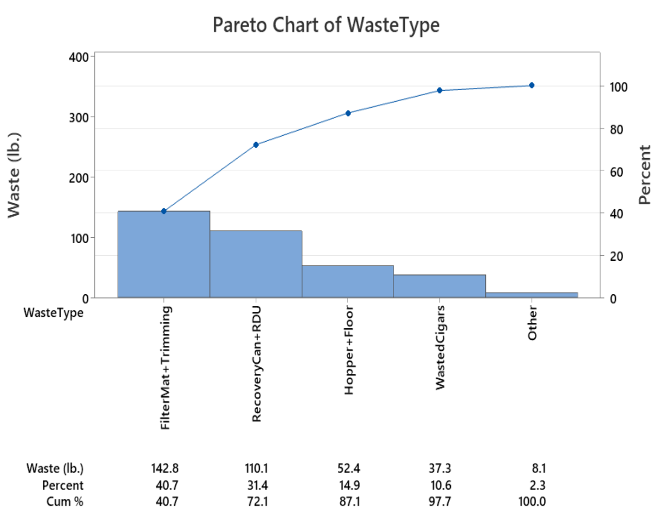

Fig. 18. Pareto chart comparing wastes by category.

Implementing the Mulch Vacuum System eliminated floor waste during machine refilling, reducing waste by 14.9% and improving operator utilization by 5%. Man-machine analysis revealed operator utilization rates of 78% for the first shift and 86% for the second, exceeding the acceptable threshold of 85%.

Waste percentages improved from 3.1% to below the 2% factory threshold after implementing SOPs and integrated systems. Documentation time was reduced from 68 seconds to 15 seconds per task, marking a 94% improvement.

The results from this project after the recommendations can be summarized as:

- Proposed SOP for Waste Collection to increase waste visibility up to 3948%.
- Implementation of Shift change checklist giving constant material availability improved by 64%
- New production layout and process, including Utility Cart and Mulch vacuum.
- Reduced Idle time
  - Operator 1st Shift 77%
  - Operator 2nd Shift 80%
  - Material handler 46%
- Reduced 9% of travel distance, which annually represents a traveled distance cost saving of $1625.40

Overall, the final objective results are shown in Table 5. All proposed objectives were achieved.

Table 5. Objective Summary

Metric	Objective	
	Initial	Achieved
Waste reduction	15%	~100%
% Utilization	5%	5%

An important future development is the investigation of the internal components of Machine M275 to identify the root causes of its high waste generation.

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