Design and Development of Automatic Bakelite Cleaner for Marilao Alerco Industrial Corporation

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Abstract

Bottleneck cause interruption to the flow of work and delays across the production process. This is where the limited capacity reduces the capacity of the whole chain. Usually, this lead to different business problems like loss of customer satisfaction and even loss of revenue. Moreover, safety is also one of the common concerns in production due to different hazards available in the workplace. This can also affect the overall productivity and bring unnecessary costs to the company. As an answer, the proponents and the management team come up with a prototype that would eliminate the bottlenecking and eventually eliminate injury to workers in the production line of kitchenware. Upon observation and breaking down the details of the current production process, they have realized that manual processes can be supported by a combination of machine basic functions. To achieve a better design, the proponents conducted a different analysis to get the best possible design option. The objective of this study is to eliminate the bottleneck and eliminate incidents of injury in this production line. Thus, achieving customer satisfaction due to fast, complete, and ensure quality and safety.

Keywords
Bottleneck, Injury, Prototype, Customer Satisfaction, Safety

1. Introduction
Marilao Alerco Industrial Corporation is a manufacturing plan of different kitchenware and medical equipment. The primary products being produced everyday are bakelite products like casserole knobs and pot handle. A major problem in the production line is the bottleneck in the filing part of bakelite products after produced. Currently, it is done by several people filing one piece at a time with poor workplace condition like no table, insufficient lighting, and prone to hand scratches and injury. As several people are doing this process, it is still clearly to be seen that it is the most time-consuming process of the production line.

1.1 Problem Statement
Doing the filing process manually takes a lot of time, effort, and manpower. During ocular observation, it is the most time-consuming process in the production line. In addition, this process has a very poor working place condition. No table, insufficient lighting, and no provided PPE. As a result many of the workers experience scratches, cuts, and abrasion on their fingers and hands because of the file tool, they even inhale the excess parts of the knob which is very unsafe for the Bakelite products are made up from Phenolic compound. Thus, lesser productivity due to injuries and

absenteeism. In terms of financial impact, it is equivalent to approximately PHP 34.5 million in lost revenue per month.

1.2 Goal statement
Eliminate the bottleneck of the system by increasing the productivity rate of the process from 31% to 90% and eliminate the frequency of injuries and absenteeism by 95% starting by February 2020.

1.3 Business Case
Eliminating the bottleneck and increasing productivity by up to 90% than the manual process will enhance customer satisfaction, eliminate the delay of completing customer orders, and utilize manpower. Reducing the chances of injury and absenteeism will improve the well-being of the workers, increase working conditions, and improve employee's morale. When translated into cost avoidance, the company will realize an estimated savings of PHP 20,000 per month.

1.4 Proposed Solution
Upon observation of the current filing process, the team has realized that the current motion in the process can be supported by a machine to hold, press, and spin the product while the file is carefully applied. To avoid injury and inhalation of the excess phenolic compound from the product, the team added safety features to the prototype by adding machine guard, and vacuum.

The prototype will increase the productivity of the process and eliminate unsafe conditions. Thus, completing the customer's order in time through resolving the bottleneck of the production line and eliminating unsafe act and condition.

1.5 Objectives

1.5.1General Objective
The main objective of this project is to design and develop an Automatic Bakelite Cleaner for the Marilao Alerco Industrial Corporation, considering the design criteria, multiple and realistic constraints such as:

- Safety
- Productivity
- Output Quality
- Sustainability, and
- Economics in conformance with applicable codes and standards.

The project must provide both breadth and depth across the range of industrial engineering design topics implied by the title and objectives of the program.
The project must improve the integrated system in an effective, efficient, sustainable, and socially responsible manner. The project must also utilize the real-world experience and business perspective.
The project must include topical areas of productivity analysis, probability, statistics, engineering economy, and human factors.

1.5.2 Specific Objective
Specifically, this project aims to:

- Increase the productivity of the specific process from 31% to 90%.
- Produce a prototype through recycling and reusing what is available resources of the client.
- Reduce injuries frequency by 95%,
- Provide safety features based on the OSHA standards on the prototype,
- Improve the output quality of the manual process.
- Produce a prototype that is from the most durable and sustainable materials.
- Produce a prototype of less than PHP 35,000.

2. Literature Review
According to a study of Systems Approach to Multiple Criteria Decision Making, modern production and managerial systems are characterized by ever increasing levels of requisite flexibility. Systems must be quickly designed and redesigned, dismantled and assembled again, resources reshuffled in the search for continuous optimum. No systems

are given any longer; if they are, then they should not be (Zeleny M. 198). To stay in market competition, business should always look for rooms of improvements especially for those who are even not achieving customer satisfaction. Moreover, A conceptual mind model is developed to facilitate a better understanding of complexity at the edge of innovation where intelligent machines will emerge as innovators of the cyber world. It was found that innovation will gradually evolve from a human-only activity to human–machine co-innovation, to incidences of autonomous machine innovation, based on the growth of machine intelligence and the adoption of human–machine (Botha, A.P. 2019). This study will be aiming to innovate a machine, producing it to a new function as a solution of the current problem in the production line. Long cycle maintenance time prediction makes the power company operate wind turbines as cost-effectively as possible to maximize the profit (Yeh, C.-H.; Lin, M.-H.; Lin, C.-H.; Yu, C.-E.; Chen, M.-J. 2019). To achieve this in the prototype, the proponents aim to install a maintenance button for easier repair and sustainable prototype.

3. Methods

The first phase of the study is the drafting of the prototype from the available resources in the plant. It is followed by listing down all possible types of the components for achieving the desired criteria. Before building the prototype, the proponents conducted Analytical Hierarchy Process, Weighted Sum, Sensitivity Analysis, and Trade-Off Analysis to achieve a sustainable, economically efficient, safest, and most productive design option while following standards applicable. Lastly is the collection of the components and assembling.

4. Data Collection

4.1 The Prototype Design

After the assessment, brainstorming, and research of possible prototype components, the proponents come up with the prototype of using the drill press machine attached with a file, vacuum, and switch operators. To achieve the greatest prototype design, there were two type per component considered for passing the criteria of safety, productivity, quality, economic, and sustainability. For the drill press, 1 Hp and ½ Hp was considered. For vacuum, 750 watts and 600 watts were considered. For file, single-cut and double-cut file is considered. For switch operators, push button operator and foot press were considered.

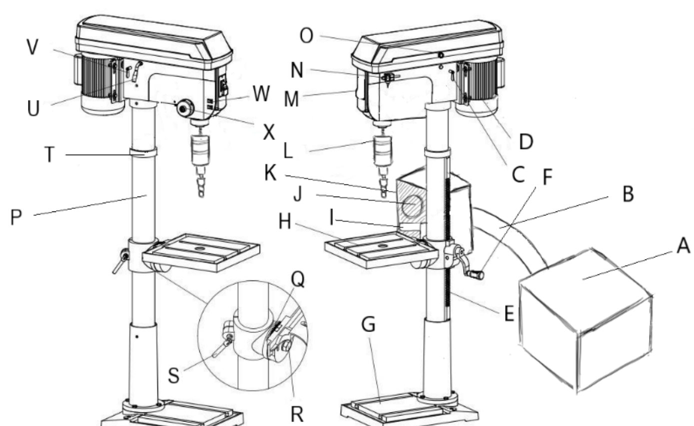

Figure 1. Initial sketch of the prototype

As Figure 1 shows the initial sketch of the prototype, the following are the equipment as shown: A-Vacuum Cleaner, B-Hose, C-Motor Locking Wing Screw, D-Motor, E-Rack, F-Table Adjustment Crank, G-Base, H-Table, I-File, J-Screen, K-Machine Guarding, L-Chuck, M-Power Switch, N-Chuck Key, O-Pulley Cover, P-Column, Q-Bevel Scale, R-Bevel Lock Bolt, S-Table Locking Handle, T-Column Collar, U-Belt Tension Adjustment Handle, V-Motor Locking Wing Screw, W-Emergency Switches, X-Spring Housing, Y-Column.

4.2 Analytic Hierarchy Process

As there are 16 design options created for the considered types of the prototype components. The proponents conducted Analytic Hierarchy Process for ranking decision alternatives and selecting the best one when the decision-maker has multiple objectives or criteria. The Table 1. Represents the Analytic Hierachy Process results

Table 1. Analytic Hierarchy Process (Result)

Design Option	**Ranking**
Drill Press: 1/2 HP Vacuum: 600 W File: Single Operator: Push-button	0.0406
Drill Press: 1 HP Vacuum: 600 W File: Single Operator: Push-button	0.0793
Drill Press: 1/2 HP Vacuum: 750 W File: Single Operator: Push-button	0.0596
Drill Press: 1 HP Vacuum: 750 W File: Single Operator: Push-button	0.1004
Drill Press: 1/2 HP Vacuum: 600 W File: Double Operator: Push-button	0.0545
Drill Press: 1 HP Vacuum: 600 W File: Double Operator: Push-button	0.1045
Drill Press: 1/2 HP Vacuum: 750 W File: Double Operator: Push-button	0.0735
Drill Press: 1 HP Vacuum: 750 W File: Double Operator: Push-button	0.1256
Drill Press: 1/2 HP Vacuum: 600 W File: Single Operator: Foot press	0.0184

Design Option	Ranking
Drill Press: 1 HP Vacuum: 600 W File: Single Operator: Foot press	0.0357
Drill Press: 1/2 HP Vacuum: 750 W File: Single Operator: Foot press	0.0523
Drill Press: 1 HP Vacuum: 750 W File: Single Operator: Foot press	0.0469
Drill Press: 1/2 HP Vacuum: 600 W File: Double Operator: Foot press	0.0285
Drill Press: 1 HP Vacuum: 600 W File: Double Operator: Foot press	0.0533
Drill Press: 1/2 HP Vacuum: 750 W File: Double Operator: Foot Press	0.0623
Drill Press: 1 HP Vacuum: 750 W File: Double Operator: Foot press	0.0644

As Table 1 shows the overall score of the design options for using the Analytical Hierarchy Process. The result of the analysis showed that the combination of Drill Press:1 HP, Vacuum 750 W, Double file, and Pushbutton operator (Option 8) is the most preferable combination and system to use for this design project.

4.3 Weighted Sum Method

The proponents also used Weighted Sum Method for it is the ene of the best formulas and simplest procedures for selecting one option from a finite set or list of n options (Cruz and Almario 2018). On selecting the best option, it will have the largest weighted sum among the other options by calculating the values of the normalized criteria.

Table 2. Overall Rank of Design Options using WSM (Result)

Design Option	Preference Vector	Ranking
1 Drill Press: 1/2 HP Vacuum: 600 W File: Single Operator: Push-button	0.541666667	11th
2 Drill Press: 1 HP Vacuum: 600 W File: Single Operator: Push-button	0.654166667	9th
3 Drill Press: 1/2 HP Vacuum: 750 W File: Single Operator: Push-button	0.691666667	7th
4 Drill Press: 1 HP Vacuum: 750 W File: Single Operator: Push-button	0.8375	3rd
5 Drill Press: 1/2 HP Vacuum: 600 W File: Double Operator: Push-button	0.541666667	11th
6 Drill Press: 1 HP Vacuum: 600 W File: Double Operator: Push-button	0.766666667	5th
7 Drill Press: 1/2 HP Vacuum: 750 W File: Double Operator: Push-button	0.741666667	6th
8 Drill Press: 1 HP Vacuum: 750 W File: Double Operator: Push-button	1	1st
9 Drill Press: 1/2 HP Vacuum: 600 W File: Single Operator: Foot press	0.379166667	12th
10 Drill Press: 1 HP Vacuum: 600 W File: Single Operator: Foot press	0.654166667	9th

Design Option	Preference Vector	Ranking
11 Drill Press: 1/2 HP Vacuum: 750 W File: Single Operator: Foot press	0.616666667	10th
12 Drill Press: 1 HP Vacuum: 750 W File: Single Operator: Foot press	0.7625	4th
13 Drill Press: 1/2 HP Vacuum: 600 W File: Double Operator: Foot press	0.541666667	11th
14 Drill Press: 1 HP Vacuum: 600 W File: Double Operator: Foot press	0.766666667	5th
15 Drill Press: 1/2 HP Vacuum: 750 W File: Double Operator: Foot Press	0.666666667	8th
16 Drill Press: 1 HP Vacuum: 750 W File: Double Operator: Foot press	0.925	2nd

As Table 2 shows the final preference vector and the overall ranking by using WSM. The analysis showed that the best design option for the prototype with the given criteria and constraints is Design Option 8 with the preference vector or 1 which is the highest among all other design options.

4.4 Sensitivity Analysis

One of the analytical tools in asserting the best possible option in the following design choices is to use the sensitivity analysis. This analysis will use the changes in weights of the criteria to determine if the winning option in the past trade-off analysis method is still the best. The winning design must show consistency in ranking or showing any evidence that this option is the most top-ranked among the other choices. The proponents used 15 combinations or run to establish the sensitivity analysis and each of the criterion which affects the design are given priority. Each design options are ranked and presented into a line graph to show the evidence.

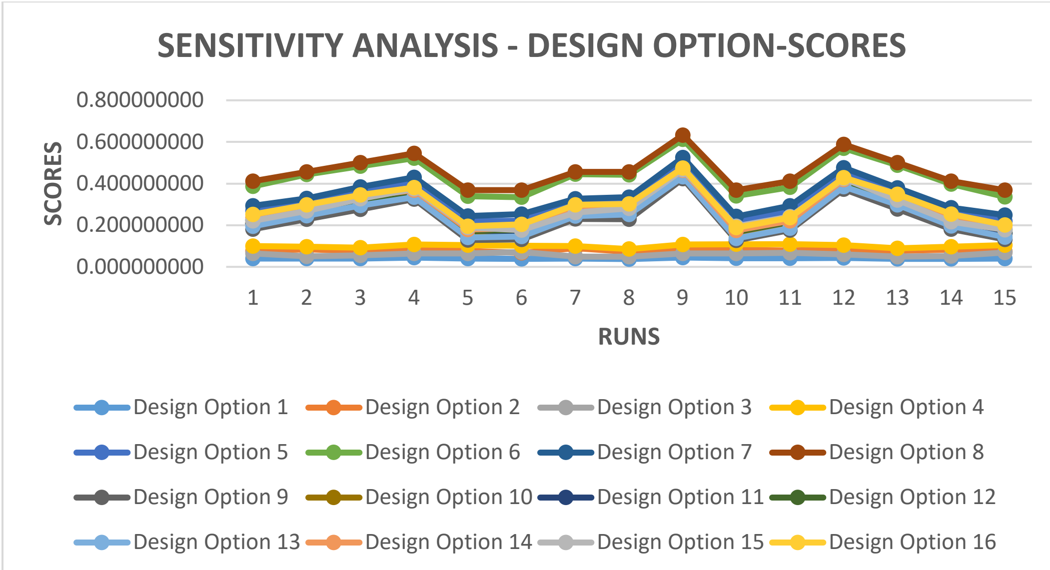

Figure 2. Sensitivity Analysis of Scores for Design Option

As Figure 2 shows the sensitivity analysis of scores, Design Option 8, which is the Drill Press:1 HP, Vacuum 750 W, Double file, and Pushbutton operator; shows that it is the highest among other Design Option.

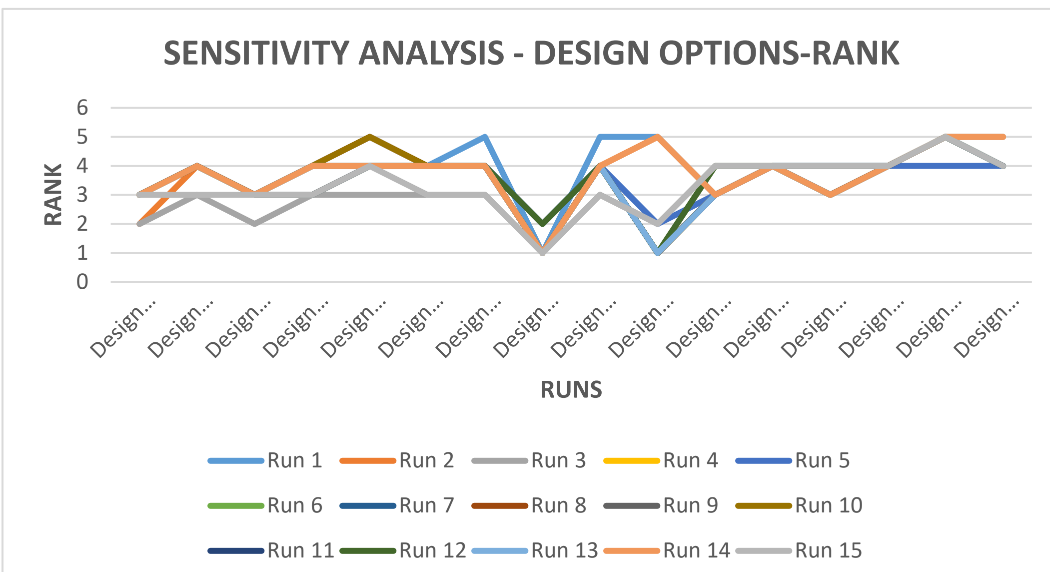

Figure 3. Sensitivity Analysis of Rank for Design Option

As Figure 3 shows the sensitivity analysis for rank, Design option 8 shows clear evidence of being the most consistent among the other options. Even the graph is fluctuating, Design Option 8 is still the best suitable choice for the prototype even if there are changes in the weights of the criteria.

4.5 Cost-Benefit Analysis

Cost-benefit analysis is the foundation of the decision-making process across a wide variety of disciples. This model is built by identifying the benefits as well as the associated costs and subtracting costs from benefits. The proponents analyzed the benefits and cost of the combined raw materials which come up with 16 design options from its criteria and analyze the net benefit of each option. The winning design option must have the highest net benefit.

Table 3. Cost-Benefit Analysis Table

	Benefits			Costs			
	Savings from medication	Machine production total cost	Profit made from the productivity	The estimated total cost of the machine	Machine Repair cost	Product rework cost	Net Benefit
Design Option 1	PHP 743.46	PHP 29,402.00	PHP 85,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 68,561.46
Design Option 2	PHP 743.46	PHP 30,272.00	PHP 95,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 79,431.46
Design Option 3	PHP 743.46	PHP 30,102.00	PHP 85,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 69,261.46
Design Option 4	PHP 743.46	PHP 30,972.00	PHP 95,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 80,131.46
Design Option 5	PHP 743.46	PHP 29,912.00	PHP 90,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 74,071.46
Design Option 6	PHP 743.46	PHP 30,782.00	PHP 100,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 84,941.46
Design Option 7	PHP 743.46	PHP 30,612.00	PHP 90,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 74,771.46
Design Option 8	PHP 743.46	PHP 31,482.00	PHP 100,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 85,641.46
Design Option 9	PHP 743.46	PHP 29,504.00	PHP 75,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 58,663.46
Design Option 10	PHP 743.46	PHP 30,374.00	PHP 85,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 69,533.46
Design Option 11	PHP 743.46	PHP 30,204.00	PHP 75,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 59,363.46
Design Option 12	PHP 743.46	PHP 31,074.00	PHP 85,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 70,233.46
Design Option 13	PHP 743.46	PHP 30,014.00	PHP 80,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 64,173.46
Design Option 14	PHP 743.46	PHP 30,884.00	PHP 80,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 65,043.46
Design Option 15	PHP 743.46	PHP 30,714.00	PHP 90,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 74,873.46
Design Option 16	PHP 743.46	PHP 31,584.00	PHP 90,000.00	PHP 31,584.00	PHP 5,000.00	PHP 10,000.00	PHP 75,743.46

As Table 3 shows the Cost-Benefit Analysis, Design Option 8 shows that it is the highest net benefit among other Design Options. This means that Design Option 8 is the best in terms of the benefits and costs from the criteria.

4.6 Trade-Off Analysis

Trade-off Analysis will determine the effect of decreasing one or more key factors and simultaneously increasing one or more other key factors in the design. In this study, the 2 best design options from the AHP, WSM, Sensitivity, and Cost-Benefit analysis will undergo Trade-off analysis to achieve the best and suitable option for the desired criteria.

Table 4. Criteria and Relative Scores

Criteria	Relative Score	Explanation of Rating
Safety	30	This criterion gets the most score to compare to other criteria because the product's main feature is the safety capability of the Bakelite machine to the workers. The product will protect the users from dust and through the cut. There will be safeguarding for the machine to protect the workers from the machine.
Productivity	25	This criterion is the second most priority compared to the other criteria because productivity and efficiency represent the rate of products that are being developed or performed or how well the task is being completed and it will be an integral part of the success of the company. It will eliminate the delays or bottlenecks in the Bakelite Department.
Output Quality	20	This criterion is the third most priority compares to other criteria because it satisfies the customers, and it retains the loyalty to continue buying on the company. It also an important contribution to long-term revenue and profitability.
Sustainability	15	This criterion is the fourth priority compares to other criteria because one's important principle of sustainable engineering is that the environmental effects of a product can be minimized in all phases of its cycle, from extracting raw materials, manufacturing to ultimately recycling or properly disposing of.
Economic	10	This criterion is the least priority compares to other criteria because it is just concerned with the total cost of the machine. The company has its machine shop, excess materials, and people who know about making and repairing the machines they use.

As Table 4 shows the weights of each criterion for building the Bakelite Machine, it also shows the importance of each criterion that is relevant to the product.

Table 5. Trade-Off Table

Criteria	Weights	Indicator	**Design Option 4** Drill press: 1HP Vacuum: 750W File Single: Single-cut Operator: Push-button	**Design Option 8** Drill press: 1HP Vacuum: 750W File Single: Double-cut Operator: Push-button	**Design Option 16** Drill press: 1HP Vacuum: 750W File Single: Double-cut Operator: Foot press
Safety	**30%**	Conformance to OSHA Machine Standards	4	4	4
		User Safety	4	4	4
		Compliance to Ergonomics	4	4	3
Productivity	**25%**	Speed requirement	3	4	4
Quality	**20%**	The quality output of the automated filing process	3	4	4
Sustainability	**15%**	The durability of the machine	3	3	3
Economic	**10%**	Overall Cost	2	2	2

Criteria	**Weights**	**Indicator**	**Design Option 4** Drill press: 1HP Vacuum: 750W File Single: Single-cut Operator: Push-button	**Design Option 8** Drill press: 1HP Vacuum: 750W File Single: Double-cut Operator: Push-button	**Design Option 16** Drill press: 1HP Vacuum: 750W File Single: Double-cut Operator: Foot press
		Market Availability of the parts	3	3	2
		Sum	**3.25**	**3.7**	**3.55**

As Table 5 shows the Trade-off Table, the Design Option 8 had the highest sum. In the rubrics created the score of 4 is the highest and 1 to be the lowest with its corresponding reason. Using the criteria and weights provided by the management, the scores are multiplied for their weight and summarized. The highest sum which is Design Option 8 is the best among the top 2 from the analysis made.

5. Results and Discussion

5.1 Numerical Results

5.1.1 Analysis Results

After all the assessment of the proponents in the current situation of Marilao Alerco, identifying the contributing factors for the problem, developing vital constraints for the design of the automatic Bakelite machine, the proponents came up with the final design of the machine. The selection of materials for the machine has undergone a Trade-Off Analysis, Analytic Hierarchy Process, Weighted Sum Method, Sensitivity Analysis, and Cost-Benefit Analysis which shows the Design Option 8 is the best among other design options. As the group compares to each other the solutions of decision-making tools, they came up with the design of combining the 1 Hp of a drill press, 750 W industrial vacuum, double-cut file with safety features such as machine guarding, installation of light and emergency buttons. As for the mechanism of the machine, the proponents came up with the push button operator. On doing the prototype, the trade-off shows that the proponents give up the criteria of sustainability for they use 100% recycled materials from the machine shop of the company avoiding total machine production cost while eliminating chances of injury by 100%, increase productivity from 31% to 106% and increase quality output.

The proponents conduct several trial tests for the operation of the prototype to test the efficiency and the productivity of the machine and the quality of knobs after filing and the safety of workers to the machine including the ergonomic features. The workers of the manual filing process are asked to use the machine for the trials. By giving up the criteria of sustainability for making the prototype the following are the improvement made by the Automatic Bakelite Cleaner from the Manual Process.

- Provide safety to the workers of the filing process and eliminate the chance of getting injured and inhaling excess Phenolic compound from the Bakelite product by 100%,
- Increase productivity by 244%,
- Increase output quality,
- Produce a prototype through recycling and reusing available parts from the machine shop of the company avoiding cost on the production of the machine,
- Enhance the facility lay-out by optimizing the floor space,
- Utilize manpower for the machine only requires 1 worker,

- Enhance the well-being and working condition of the workers because of safety and ergonomic features on the machine.

Table 6. Summary of Findings of Materials from Trade-off Analysis

Design Options	AHP	WSM
1) Drill Press: 1/2 HP Vacuum: 600 W File: Single Operator: Push-button	0.0406	0.541666667
2) Drill Press: 1 HP Vacuum: 600 W File: Single Operator: Push-button	0.0793	0.654166667
3) Drill Press: 1/2 HP Vacuum: 750 W File: Single Operator: Push-button	0.0596	0.691666667
4) Drill Press: 1 HP Vacuum: 750 W File: Single Operator: Push-button	0.1004	0.8375
5) Drill Press: 1/2 HP Vacuum: 600 W File: Double Operator: Push-button	0.0545	0.541666667
6) Drill Press: 1 HP Vacuum: 600 W File: Double Operator: Push-button	0.1045	0.766666667
7) Drill Press: 1/2 HP Vacuum: 750 W File: Double Operator: Push-button	0.0735	0.741666667
8) Drill Press: 1 HP Vacuum: 750 W File: Double Operator: Push-button	0.1256	1
9) Drill Press: 1/2 HP Vacuum: 600 W File: Single Operator: Foot press	0.0184	0.379166667

Design Options	AHP	WSM
10) Drill Press: 1 HP Vacuum: 600 W File: Single Operator: Foot press	0.0357	0.654166667
11) Drill Press: 1/2 HP Vacuum: 750 W File: Single Operator: Foot press	0.0523	0.616666667
12) Drill Press: 1 HP Vacuum: 750 W File: Single Operator: Foot press	0.0469	0.7625
13) Drill Press: 1/2 HP Vacuum: 600 W File: Double Operator: Foot press	0.0285	0.541666667
14) Drill Press: 1 HP Vacuum: 600 W File: Double Operator: Foot press	0.0533	0.766666667
15) Drill Press: 1/2 HP Vacuum: 750 W File: Double Operator: Foot Press	0.0623	0.666666667
16) Drill Press: 1 HP Vacuum: 750 W File: Double Operator: Foot press	0.0644	0.925

As Table 6 presents the Summary of Findings of Materials from Trade-off Analysis, it shows the best design option among the 16 combinations for the Automatic Bakelite Cleaner. Through the use of AHP, WSM, Sensitivity Analysis, and Cost-Benefit Analysis the proponents come up with the best combination of 1hP Drill press, 750 Watts Industrial Vacuum, Double-cut file, and Push-button operator with the final preference vector of 0.1256 for AHP and 1 for WSM which is the Design Option 8.

5.1.2 Output Comparison

After coming up with a final design, the proponents compared the output of the current process and by using the finished prototype. It shows that there is a drastic change of productivity by having the new prototype in the process by 244%.

Table 7. Output Comparison

Trial	Knobs/hour (Automated Machine)	Near Miss Injuries	Knobs/hour (Manual Operation)	Near Miss Injuries
1	1425	None	409	1
2	1442	None	414	2
3	1388	None	422	0
4	1429	None	413	1
5	1379	None	397	0
6	1439	None	421	0
7	1423	None	417	1
8	1398	None	385	0
9	1425	None	419	1
10	1406	None	418	1
Output per day	14,154 pcs	0%	4,115 pcs	60%

As The table 7 provide the output comparison, it shows the number of finished knobs per hour of the Automatic Bakelite Machine versus the Manual Filing, total output of the day and the percentage of getting injuries.

New Productivity: $= \frac{Prototype\ Output - Manual\ Output}{Manual\ Output} \times 100$

New Productivity: $= \frac{14{,}154 - 4{,}115}{4{,}115} \times 100 = \mathbf{244}\%$

5.2 Graphical Results

The final product design is Design Option 8, the best option among the other Pareto optimal options. The combination of the materials of 1hP Drill press, 750 Watts Industrial Vacuum, Double-cut file, and Pushbutton operator. The applications used are Sketchup and Taka Vray.

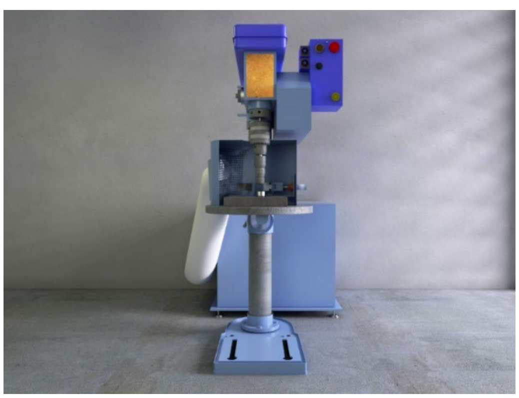

Figure 4. Final Product Design 3D Model (Front view)

As Figure 4 shows the front view, it is clearly almost the same equipment but in different function.

Figure 5. Final Product Design 3D Model (Higher Front view)

As Figure 5 shows the higher front view, it is showing the buttons and the platform for the bakelite product.

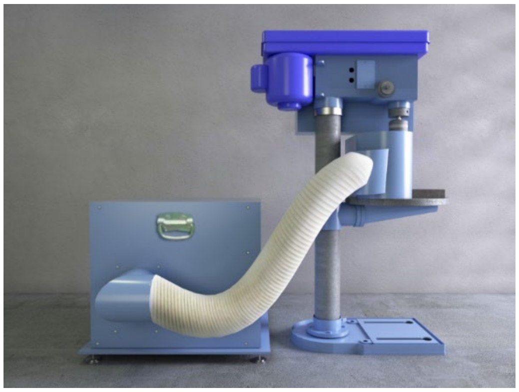

Figure 6. Final Product Design 3D Model (Right-side view)

As Figure 6 shows the right-side view, it shows the hose of the vacuum from the platform where the excess phenolic compound will be absorbed.

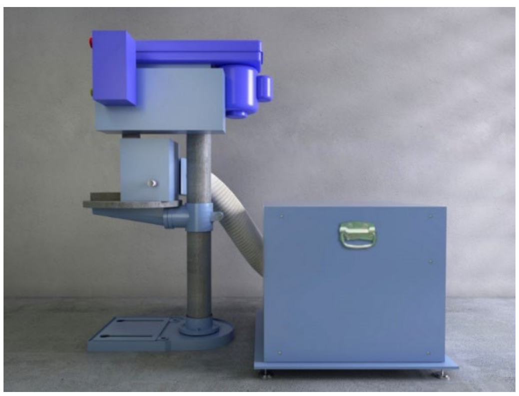

Figure 7. Final Product Design 3D Model (Left-side view)

As Figure 7 shows the left-side view, it shows the area added to the drill press and also the vacuum.

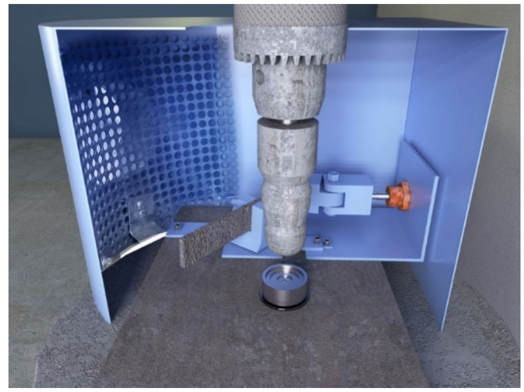

Figure 8. Final Product Design 3D Model (Working area)

As Figure 8 shows the working area of the equipment, it is clear that the drill press will push the bakelite product while spinning and the file is ready for its work together with the vacuum.

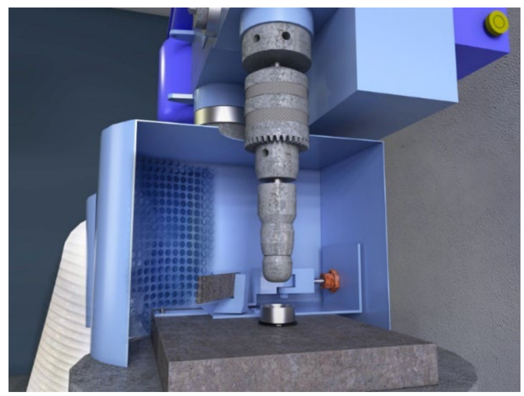

Figure 9. Final Product Design 3D Model (Working area)

As Figure 9 shows the working area of the equipment, it emphasizes the platform and the modified pin for the drill press.

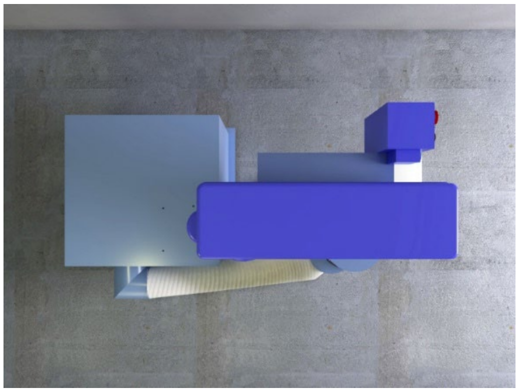

Figure 10. Final Product Design 3D Model (Top view)

As Figure 10 shows the top view, it shows that the equipment is just almost a drill press and vacuum.

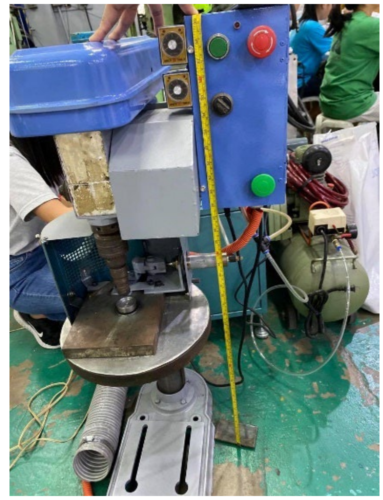

Figure 11. Final Product Design (Actual photo)

As Figure 11 shows the actual photo of the equipment done assembling. It is clear that it is not that far from the 3D Model and serves its purpose well.

6. Conclusion

As the proponents conducted trade-off analysis, sensitivity analysis, and cost-benefit analysis and compare each using decision-making tools, the winning option for this product is the Design Option 8 with the combination of 1 Hp of Drill Press, 750 W Vacuum Blower, Double-cut file, and Push-button operation with safety features such as machine guarding, installation of light and emergency buttons. After producing the prototype, the proponents tested the machine with 10 trials. The productivity has increased by 244% with the chances of not getting injured by 100%. With this, the company will now complete customer's orders in time, and no workers will get injured because of the safety features of the machine.

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