Improving Efficiency of Shoe Manufacturer through the Use of Time and Motion Study and Line Balancing

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***Abstract*—Manufacturing footwear is the number one source of income in Marikina City, Philippines. But, it is now facing a great challenge due to globalization. Imported shoes from China continue to threaten the profitability of Philippine made shoes. For the shoe makers of Marikina, being productive by means improving the processes, cost reduction of raw materials, and increasing efficiency are some of the best options since these do not require additional worker and machinery. In this study, the researchers use TMS and line balancing technique to increase efficiency of production line.**

***Index Terms*—Efficiency, TMS (Time and Motion Study), line balancing**

I. Introduction

Le Schu's Manufacturing, Inc. is a small scale company located in Kalumpang, Marikina, Philippines. The company had been producing different kinds of shoes for men and women of all ages for the past few years. The company created a good image by strengthening the bond between suppliers and customers. However, having a good image is both a blessing and a challenge. In a short span of time, the demand for a particular line of shoe, the success shoes, doubled. Due to this, the capacity of machine and personnel cannot meet the demand. On a day-to-day operation, the management focus on the orders that is due soonest.

As a result, the company expedite every order, until none of the schedules has been implemented. They adapt this system behavior to cope with the current demand. They adapt the self-learning production systems (SLPS). In reference [4], Orio, et al, demonstrates the applicability of SLPS methodology and conclude that companies have capabilities to learn and to evolve throughout system life cycle.

Although the company manage to continue operation without proper application of production systems, many complications arise and the company started to miss deliveries.

Producing a pair of footwear requires a systematic approach. It takes too much time achieving a good quality output of shoes because it undergoes into various manual processes. That is why it needs to have an organized facility layout and schematize the method accordingly.

To fully understand the whole process, the researchers went to the company several times to gather data and document the process. Reading related literature also help the researchers know the current innovation in shoe processes such as the application of Lean Manufacturing. In reference [2] Gati-Wechsher and Torres documented the use of concepts in the innovation of product in a large company of athletic footwear in Brazil. Although there are several continuous improvement methods that can be applied in shoe manufacturing industry, Talib Bon and Ariffin [5] conclude that the combination of a work process, time measurement and production layout will improve efficiency effectively (p. 10).

A. Time and Motion Study (TMS)

Freivalds [1] explain that work measurement techniques such as stop watch time study, standard data and time formulas represent a better way to established fair production standards (p.405). Freivalds signify that "accurately established time standards make it possible to increase the efficiency of the equipment and the operating personnel while poorly established standards, although better than no standards at all, leads to high cost, labor dissension, and possibly even the failure of the enterprise" ref. [1] (Freivalds, A., 2014, p. 406).

Among all continuous improvement methodologies, according to Mayank [3], no single method can be crowned as the best (p.75). But, in his research entitled Improving Productivity in small scale industry, Mayank used Time and Motion Study (TMS).

B. Line Balancing

Line Balancing is the term used when everyone is working together in a balanced fashion. Everyone is doing the same amount of work to customer requirement. The variation is smoothed, no one is overburdened, and no one is waiting. Line balancing help companies achieved all these through quantitative methods.

II. Existing Data Gathered

Although the company is producing a number of different lines of footwear, this paper will only focus on one line brand of shoes, "success" line brand.

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The Company is operating eight hours per day, and five days a week. Their daily desired output is 250 units, but they are only producing 120 shoes per day.

Table I shows the flow process of the company manufacturing "success" shoes. It has a total of 16 operations, 8 transportations with a total travel distance of 25.21 meters, no delay, 3 inspections, and 1 storage. The current total time to produce 1 pair of success shoes is 13.18 minutes.

The task times shown in Table I were obtained through TMS.

Fig. 1 shows the current process layout of the line brand "success" shoes inside the company's facility. It locates where the operations, transportations, inspections, and storage happen. It is in accordance with the sequence presented in Table I.

TABLE I. PRESENT FLOW PROCESS CHART OF SUCCESS SHOES

Description	Symbol	Time(min)	Distance(m)	REMARKS
Get raw materials from storage	●	0.1164		
Transfer to the rubber cutter	➡	0.094	1.6723	
Cut raw materials	●	1.167		
Transfer to storage	➡	0.082	1.14864	
Inspect	■	0.0211		
Transfer to assembly table	➡	0.4066	6.6890	Must be place adjacent to inspection to reduce distance
Apply adhesive to ribbon	●	0.057		
Transfer to bottoming and lasting table	➡	0.1016	1.7652	Connecting two tables will eliminate transport
Attach ribbon to entrada	●	0.3101		
Transfer to storage	➡	0.167	6.9677	
Inspect	■	0.0432		
Transfer to finishing and packaging table	➡	0.0895	5.2955	Must be place adjacent to inspection to reduce distance
Apply adhesive to entrada and insole	●	0.4429		
Attach shoe last and insole	●	0.0686		
Attach entrada and tack nails	●	0.2721		
Transfer to oven	➡	0.0778	0.5574	Additional oven is needed
Heat	●	4		
Apply adhesive to sole	●	0.4695		
Attach sole	●	0.5602		
Dry	●	0.6742		
Remove shoe last	●	0.5899		
Inspect	■	0.1188		
Apply shoe wax	●	2.192		
5678Dry Shoes	●	0.4889		
Polish Shoes	●	0.3266		
Packaging	●	0.1624		
Transfer to storage	➡	0.0834	1.1148	
Store	▼			Storage are must place Adjacent to Packaging area

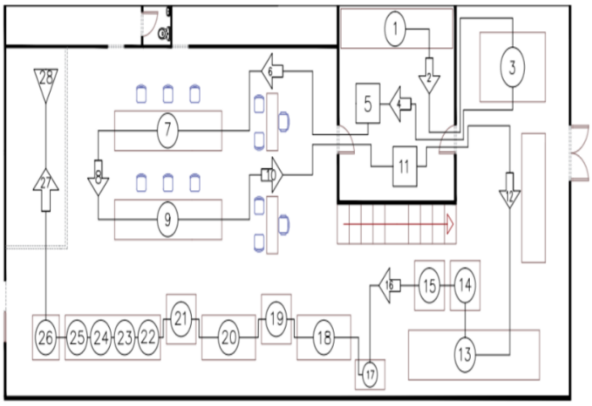

Figure 1. Present flow diagram.

III. PROBLEM ANALYSIS

A. Heat Process

The heating process is done by putting the shoes inside the oven. This is essential because the adhesive is more effective if you apply it in dry surface than a wet surface. The heating process is the bottleneck, from table 1, because it has the highest task time than the rest of the task. The company only has one oven, and this existing oven has an output of 120 shoes per day.

Output of oven = operating time per day / task time

Output of oven = 480 min / 4 min = 120 units

B. Transportation

Fig. 1, the present flow diagram, shows that there are too many transportations in the Company's process. Also, the distance between two operation processes is too long such as between operations 7, which is the application of adhesive to ribbon, and operation 8, which is attaching the ribbon to entrada.

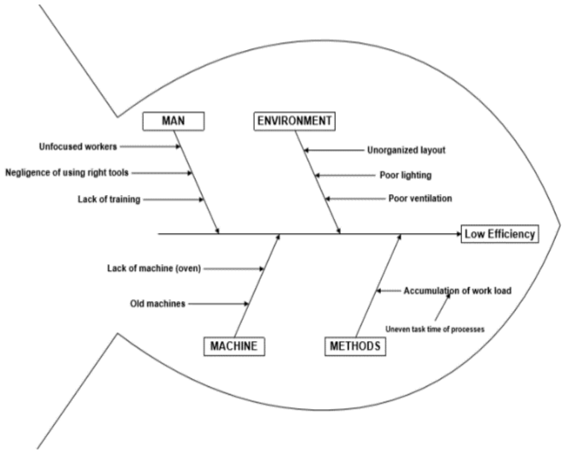

Figure 2. Ishikawa diagram

C. Production Line Set up

On the 27th day of July 2015, the researchers found out that the enterprise is experiencing low efficiency caused by the current work setup in the production line of "success" shoes eventually resulting delays and excess time consumption between processes, which is because of the unorganized area of their assembly. As the group observes the facility of the company, the group noticed that they are not using their resources accordingly. Fig. 2 shows the different factors that contribute or affects the present production line set-up of the "success" shoes line brand.

1) **Man**. The researchers observed the workers in the production area and noticed that some are not focusing on their assigned tasks and still managed to do some conversations with others. In the upper assembly department, workers are not using the right tools needed for the process. Instead, they are just using their bare hands on applying the adhesive. Also, the company employed newbies, who do not undergo intensive training, they were only given instructions.
2) **Machine.** The oven machine has a fixed number of outputs of 120 shoes per day and can contribute to the company's low-efficiency rate. Some old machines need maintenance. There were times that those devices are not operational, thus interrupting the whole production.
3) **Environment.** There are a lot of dark areas, and some parts are only dimly lighted. During the visit, adhesive's odour emanates the entire production area that affects the worker's performance. Also, one of the major contributors that affect the efficiency of the production is the company's unorganized layout.
4) **Methods.** After the group conducted time and motion study, the group found out that the current setup of the production has an uneven task time of processes resulting in workload accumulation. The company cannot obtain their desired output per day.

IV. Problem Statements and Objectives

A. Problem Statements

1) The desired output rate of "success" shoes is 250 units, but the company is currently producing 120 units.
2) The number of transportation processes is 8 with the workers' total distance travel of 25.21054 meters for the transportation of materials. Considering that the transportation is a waste.
3) The current work setup of the "success" shoe line is found to cause a slowdown in the production. That includes the problems in man, machine, environment, and layout.

B. Objectives of the Study

1) To increase current output rate from120 units per to the target 250 units per day.
2) To reduce the number of transportation, and lessen the distance travel by at least 5 meters
3) Modify the work set up for it to support the production rate effectively

V. Current Efficiency Ratio

To know the current efficiency of the process, the researchers used line balancing. Figure 3 shows the precedence diagram that represents the list of processes used in assessing the current efficiency ratio of the production. It also shows the time it takes to finish the process. There are 19 processes, comprised of 16 operations and 3 inspections. The transportation is not included in the line balance. Adding up all the task times, the production line has a total of 12.0809 minutes.

Operating time per day = 8 hours X 60 min = 480 min

Equation 1 is use to know the cycle time of the current production system.

$$Cycle\ Time\ (CT) = \frac{Operating\ time\ per\ day}{Desired\ output} \tag{1}$$

$$Cycle\ Time\ (CT) = \frac{480\ mins.}{250\ units} = 1.92\ mins./units$$

To be able to accommodate the demand, the company needs to produce 1 unit every 1.92 minutes.

To identify the number of workstation needed, equation number 2 is used. For the summation of task times, refer to Fig. 3.

$$No.of\ workstation\ (N) = \frac{\sum task\ time}{Cycle\ Time} \qquad (2)$$

$$No.of\ workstation\ (N) = \frac{12.0809\ mins.}{1.92\ mins./units} = 6.29 \approx 7$$

The theoretical minimum number of the workstation to minimize the cost of manpower and number of machines is 6.29 congruent to 7 workstations.

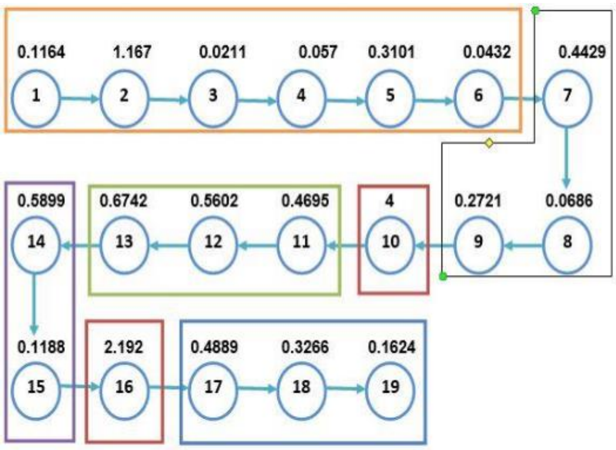

Figure 3. Precedence diagram with assigned task to work station

To compute for the idle time refer to Table II, the researchers used equation number 3 to know the percent idle time.

$$\%\ idle\ time = \frac{\sum idle\ time}{(N)(CT)} \qquad (3)$$

$$\%\ idle\ time = \frac{3.7111}{(7)(1.92)} = 27.61235 \approx \mathbf{27.61\%}$$

TABLE II. COMPUTATION OF IDLE TIME FOR CURRENT SET UP

WORKSTATION	TASK TIME (min)	ELIGIBLE	ASSIGN TASK	UNASSIGNED TIME (min)	STATION IDLE TIME (min)
1	0.1164	1	1	1.8036	
	1.167	2	2	0.6366	
	0.0211	3	3	0.6155	
	0.057	4	4	0.5585	
	0.3101	5	5	0.2484	
	0.0432	6	6	0.2052	**0.2052**
2	0.4429	7	7	1.4771	
	0.0686	8	8	1.4085	
	0.2721	9	9	1.1364	**1.1364**
3	4	10	10	0	**0**
4	0.4695	11	11	1.4505	**0**
	0.5602	12	12	0.8903	
	0.6742	13	13	0.2161	**0.2161**
5	0.5899	14	14	1.3301	
	0.1188	15	15	1.2113	**1.2113**
6	2.192	16	16	0	**0**
7	0.4889	17	17	1.4311	
	0.3266	18	18	1.1045	
	0.1624	19	19	0.9421	**0.9421**
$\sum idle\ time$					**3.7111**

The current efficiency ratio can be now computed based on the percent idle time. Refer to equation number 4.

$$efficiency = 100 - \%\ idle\ time \qquad (4)$$

$$efficiency = 100 - 27.61\% = \mathbf{72.39\%}$$

VI. RECOMMENDATIONS

A. Buying a Brand New Oven

Doubling the oven will double the output since the heating process is the bottleneck on this production. If the current oven can produce an output of 120 units, given that the oven is quite old. Buying the brand new one can have an operating performance of at least 10% higher which means brand new oven can produce 120 plus 12 units (10% of 120). Adding the current 120 and the output of brand new oven of 132 will give an outcome of 252 units.

B. Re-Layout

The relationship between the distance travelled and the time needed to make it from one point to another is directly proportional, the relationship between the distance travelled and the energy exerted by the worker is also directly proportional, therefore, reducing the gaps between the processes reduces the time and energy used by the operator.

More time saved in each process means that they can increase their target number of finished products per working day.

Having these observations, the researchers use affinity chart to analyze the current floor layout and propose a process flow that will lessen the distance between the operations that are highly related to each other. The diagram in Fig. 4 shows the changes in the distances between processes.

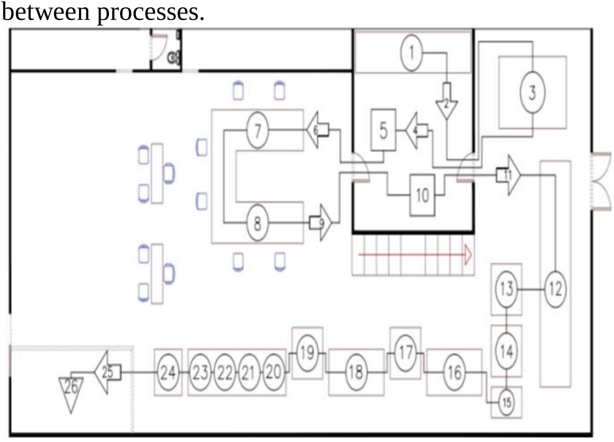

Figure 4. Proposed flow diagram

The operations, inspections and transportations you have seen in Fig. 4 are in conjunction with Table III. Notice the changes in the layout of operations number 7, which is applying the adhesive to ribbon, and number 8, which is attaching the ribbon to entrada. The U-shape production area reduces the number of transportation as well as time and energy of the workers. Also notice the changes in operations 12, 13, 14 in the proposed flow diagram. This is where the odour of adhesive emanates when the group visits the company. Comparing it with the current flow diagram, the proposed saves time due to the reduction of the long distance between the inspection area, and the area where adhesives are applied to entrada and insole in the preparation of attaching the shoe last and insole.

Table III shows the proposed flow process chart. It is the output of (1) reducing the distance travelled by the materials, (2) combining elements into one workstation, and (3) simplifying the process performed in producing success shoes. Implementing these modifications result in a reduction in the number of transportation by a total of 8.73 meters. Thus, the researchers were able to lessen the distance travelled by more than 5 meters, which the researchers set in the specific objectives of this study.

There is also a reduction of time. We know that transportation is a waste. Most of the manufacturing firms with advanced technology eliminate the wastes of transportation by using conveyors. Since the Company do not have conveyors, the time reduction is just small. From table number 3, the total manufacturing time of one unit is 12.9142 minutes. Re-layout will give an output of 12.0809 minutes producing one unit.

C. *Additional One Manpower to Application of Shoe Wax Operation*

The researchers recommend adding additional manpower particularly in applying shoe wax operation (the operation that consumes too much time, next to the heating operation). The purpose of this is to equalize and to balance with the other processes in terms of output and time. And, to promote smoother flow with proper arrangement of processes.

TABLE III. PROPOSED FLOW PROCESS CHART

Description	Symbol	Time(min)	Distance(m)
Get raw materials from storage	●⇨D□▽	0.1164	
Transfer to the rubber cutter	○➡D□▽	0.094	1.6723
Cut raw materials	●⇨D□▽	1.167	
Transfer to storage	○➡D□▽	0.082	1.14864
Inspect	○⇨D■▽	0.0211	
Transfer to assembly table	○➡D□▽	0.4066	6.6890
Apply adhesive to ribbon	●⇨D□▽	0.057	
Attach ribbon to entrada	●⇨D□▽	0.3101	
Inspect	○⇨D■▽	0.0432	
Transfer to finishing and packaging table	○➡D□▽	0.0895	5.2955
Apply adhesive to entrada and insole	●⇨D□▽	0.4429	
Attach shoe last and insole	●⇨D□▽	0.0686	
Attach entrada and tack nails	●⇨D□▽	0.2721	
Transfer to oven	○➡D□▽	0.0778	0.5574
Heat	●⇨D□▽	4	
Apply adhesive to sole	●⇨D□▽	0.4695	
Attach sole	●⇨D□▽	0.5602	
Dry	●⇨D□▽	0.6742	
Remove shoe last	●⇨D□▽	0.5899	
Inspect	○⇨D■▽	0.1188	
Apply shoe wax	●⇨D□▽	2.192	
Dry Shoes	●⇨D□▽	0.4889	
Polish Shoes	●⇨D□▽	0.3266	
Packaging	●⇨D□▽	0.1624	
Transfer to storage	○➡D□▽	0.0834	1.1148
Store	○⇨D□▼		

D. *Use of Personal Protective Equipment (PPE) and Training for the Workers*

The smell of adhesive in some part of the production area is too strong that affects the performance of the workers. The researchers recommend the use of face mask to lessen the strong smell that could lead to minor headache and could also lead to the feeling of irritability of the workers. Workers should also have a proper training every now and then about the proper execution on the assigned process and training about safety on how to use the proper equipment so that even the machines, equipment and tools will also be well maintained.

VII. EVALUATION

The group use the line balancing to know the efficiency of the proposed modifications. We would like to know how much the efficiency would increase having a brand new oven, bring highly related processes near with each other, and give some variable allowances for the workers comfort ability.

A. *Efficiency Rate Calculation having all the Modifications*

Additional Formulas Used applying allowances

$$NT = Performance\ Rating\ X\ Observed\ Time \tag{5}$$

$$\text{ST} = \text{(NT) X (1+ Allowance Factor)} \tag{6}$$

Wherein NT = Normal Time

ST = Standard Time

Having an additional oven, and considering to re-layout the whole production area in such a way as shown in Fig. 4 will increase the efficiency by 6.78per cent. Fig. 5 shows the modification of having additional oven and additional manpower in shoe wax application process. It is the same as in Fig 3 except for Heating process and Application of shoe wax process (both in red box). Since we have additional oven, machine will be doubled, the task time on that particular element will be cut into half, and since we have additional one worker in shoe wax application section, manpower will be doubled and the time on that particular element will cut into half.

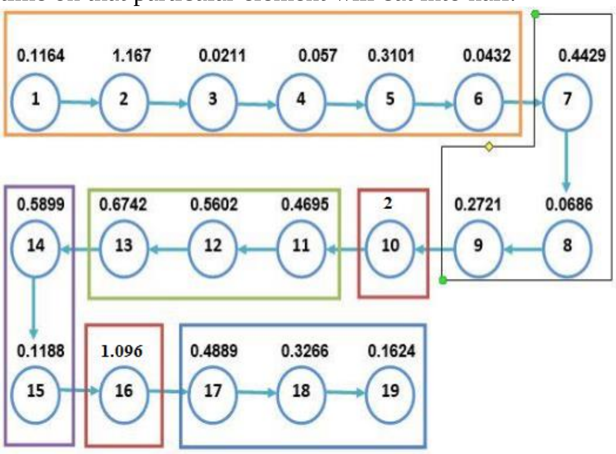

Figure 5. Proposed precedence diagram

$$Cycle\ Time\ (CT) = \frac{Operating\ time\ per\ day}{Desired\ output}$$

$$Cycle\ Time\ (CT) = \frac{480\ mins.}{250\ units} = 1.92\ mins./units$$

No. of workstations = ∑ task time / CT

= 8.9849 min / 1.92 min = 4.68 ≈ 5

The theoretical minimum number of workstation is 5. This means that the number of workstations could be greater than 5 but not less than 5.

Workstation No. 1 (the orange box in Fig. 5) has a total of 1.7148 minutes. The idle time is 0.2052, which is obtain by subtracting the total from CT 1.92 minutes.

Work Station No. 2 (Black L-Shaped box in the upper right side of Fig 5) has a total of 0.7836 minutes of efficient time, and 1.1364 (1.92 - 0.7836) minutesof idle time.

Work Station No. 3 (Red box comprising 2 min) is the heating process. The bottleneck of the operations. It dictates the output per day of the whole success shoes line production. Since is acquire 2 min, which is greater than the CT, it will have no idle time.

Work station No. 4 (the green box) comprises of 1.7039 minutes of efficient time and a 0.2161 minutes of idle time

Work Station No. 5 is the group of Operations 14, 15, and 16 in Fig 5. It has a total efficiency time of 1.8047 minutes (the sum of 0.5899, 0.1188, and1.096). Since adding operations number 17 will result to greater value than the CT, Operation number 17 should not be added, and a work station number 6 is needed to create since 5 is the theoretical minimun number of workstation. The idle time of station number 5 is 0.1153 minutes.

Work Station number 6 has a effiency of 0.9779 munites and an idle time of 0.9421 minutes.

To compute for the percentage idle time, just add all the idle times from worstations 1 to 6, and divide it to the product of CT and the number of workstations.

%idle time = [2.6151 / (6 X 1.92)] = 22.70 %

Efficiency = 100 – 22.7 = 77.3%

Based on the figures shown above, the present efficiency was increased from 72.39% to 77.30%. Therefore, the proposed modifications are effective. Furthermore, achieved the goal of the researchers.

VIII. Conclusion

Using TMS, the researchers knew easily where the bottleneck is. Identifying your takt time, the 1.92 minutes/unit, from the desired output helps in knowing which processes are taking too much time that contributes to the delay of whole production process. There are only two elements that have a higher cycle time than the takt time. One is heating process, which took 4 minutes to be done, and the other one is the shoe wax application, which needs 2.192 minutes before proceeding to the next elements. The additional oven can double up the output for the heating process. Since the heating process is the number one bottle neck, it must be the priority, modifications on other process may lead to astray since the heat process is the one that controls the output of the overall production system. The addition of one worker on the shoe wax application process also reduce the number of workplaces. Even though we hire a new worker, the cost of additional worker on the production system is better than the cost of loss of a customer for delay in production.

The results of the application of concepts and theories of methods study and line balancing state that the company can save as much as 25.63 per cent of time[(8.9849 – 12.0809) / 12.0809] and a distance travel by the materials will be reduced by34.63 per cent [(16.48 – 25.21) / 25.21] in meters based on proposed ways of improvement. The company's idle time was decreased by 17.78 % [(proposed – present) / present] while the efficiency increased by 6.78 % (from 72.39% to 77.30 %).

Appendix A Affinity Chart

Legend:

A	Absolutely required proximity
E	Especially important
I	Important
O	Ordinary importance
U	Unimportant
X	Closeness undesirable

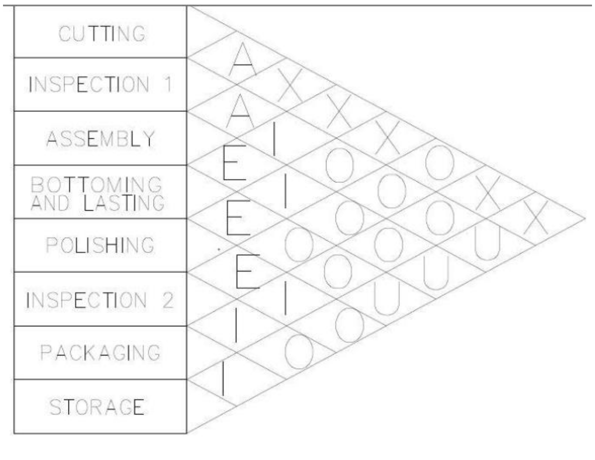

Figure 6: Affinity Chart

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To Sir Richard Abayhon[1] for enlightening us more about Methods Study

1 Engr. Richard Abayhon, MSEngMgt is an IE Faculty member at Technological Institute of the Philippines and also a Professional Services Sr. Pricing Analyst at NetSuite Philippines.

And lastly, to our friends, classmates, and family who always support us in terms of physical, emotional, mental, and financial.

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