Group No: 08

Final report

ME4072

Thavam Motors

By

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1 INTRODUCTION

Thavam Motors is a company based in the Jaffna district that specialises in the production of water pumps and complementary products. Like many industries in the northern region, Thavam Motors was forced to shut down during the war period in the 1990s. However, it was revived in the 2000s thanks to the efforts of the determined entrepreneur Mr. Thavachelvan.[1]

2 BACKGROUND

Thavam products are renowned for their quality, offering extended durability that can withstand the challenging conditions of Jaffna.

• Thavam Motors produces several items of watering system.

• Electric power motors in different capacity (1/4HP, 1/2HP, 3/4HP, 1HP, 2HP)

• Pumps and impellers in different capacities

• Couplings in several sizes

• Pull valves for relevant pump size.

• Hand water pump

To produce the above items, they use several materials concerning their properties. There is a higher probability of corrosion, because the northside is surrounded by sea. Therefore, they use white cast iron for the motor rotor axis. For the same reason, they use brass in the impeller and pump casing.

To facilitate the production, they have several types of machinery including CNC machines, Lathe machines, 3D printers, thread cutting machines, drilling machines, grinding machines and hydraulic presses.

3 PROBLEM DEFINITION

During the field visit, we observed several problems in their production line. These issues greatly hinder productivity.

• Lack of Productivity: Productivity is normally defined as the ratio of output versus input material. Thavam Motors, they do sand casting for motor casing, pump and other complementary equipment. Due to cleaning them, they waste more material.

• Workplace design

▪ Poor layout plan: they don’t have a proper layout plan. Their current layout is shown below. This is an inefficient conveying method and consumes more shifting time.

▪ Poor lighting: They do not consider light comfort according to the IESNA lighting standard. It reduces the quality of the work.

• Poor performance rating of the workers: According to our observation some workers were working at below standard processing time.

• Scrap cost: While cleaning and polishing the casted parts, there are certain amounts of parts that get damaged. The cost spent until now can be scrapped.

• Process delay: They do cast in 2 days per week and have only one CNC method even though there are several workstations for other working process. Therefore, there will be some process delay.

4 AIM AND OBJECTIVES

Aim: Analyse and identify the opportunities to improve performance and efficiency of the company through the application of industrial engineering principles.

1. Implement quality control for their production.

2. Develop and implement a new layout plan to improve workflow efficiency.

3. Audit and upgrade lighting fixtures to meet IESNA standards.

4. Implement performance tracking systems for individual worker productivity.

5. Use plant simulation and optimize scheduling to maximize CNC machine utilization.

5 DATA COLLECTION

During our last visit, we managed to collect some data. However, we were unable to gather all the required data because we visited on a Saturday, resulting in half of the employees being absent.

About their motor pump details

Motor horse power (H)	Pump inlet and outlet size	Selling Prices (Rs)
3/4	11/2” x 11/2”	52 700
¾(Oliver)	1” x 1”	27 700
¾(Oliver)	11/2” x 11/2”	30 000
1	2”x11/2”	62 700
1 1/2	2” x 2”	67 3200
2	2” x 2”	78 000

Table 1: motor pump details

Part	Weight of Output material (Kg)	Weight of Input material (Kg)
Motor casing	6	8
impeller	0.325	0.9
pump	2.4	3.1

Table 2: productivity analysis

Working time 8 AM- 5 PM

No of workpieces were done using lathe operation.

products	No of pieces
Coupling step cutting	130
Coupling Thread cutting	120
Pull valve	35

Table 3: worker observation details

Defects percentage in a week

products	Percentage (%)
Pull valve	1/30 x 100
Pump	1/10 x 100
impeller	1/20 x 100

Table 4: scrap material data

Monthly they produce 300 motors per month.

Operation	No of workers
Casting & molding	5
Manufacturing	12
CNC operation	2
Lathe operation	6
Assembling	5
Painting	1
Marketing and & Service after sell	10
Total	31

Table 5: number of workers in each sector

6 ANALYSIS OF DATA

We have conducted a detailed analysis of time consumption to identify the area for optimization. Calculated values are updated to the following table.

Parts	1st operation	2nd operation
Motor backside casing	5 min 52s	
impeller	40s	3 min
coupling	2min	1min

Table 6: time taken for each CNC cutting operation

Layout planning of the company is illustrated in the following picture and we are working on it to utilize the material handling delay and optimize the flow. Material handling distance for each job is being identified.

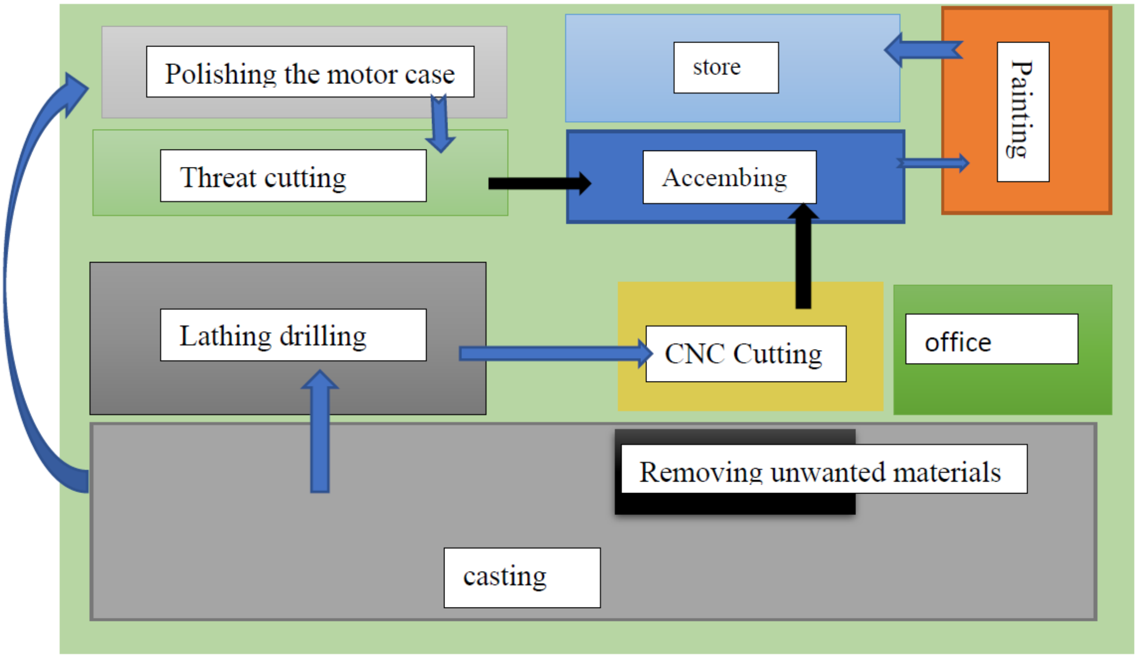


Figure 6.1: their factory layout

They used direct sunlight for lighting up the workstation in most common situations unless any rainy or low light conditions. Calculation for finding out the current illumination are on process. The main light fixture diagram is being investigated and the IESNA standard lighting needs are compared to find out the exact visual comfort of the workers.

7 FINDINGS

7.1 Audit and upgrade lighting fixtures.

Issue: High noise level

Noise levels that are measured within a 1-foot distance of each machine are shown in the following table.

Table 7.1: machines and it's sound level

Machine	**Sound level (dB)**
CNC Machines	92dB
Lathe Machines	77dB
3D Printers	50dB
Drilling Machines	85dB
Thread Cutting Machines	80dB
Grinding Machines	110dB

According to the American standard of audible comfort, the safe noise level is 85 dB for 8 hrs and the maximum noise level which is not recommended even for 1 second is 140dB for adults (Kang, 2019). Here it can be observed that CNC machines and grinding machines are beyond the safe level of noise. Therefore, the following actions should be taken to reduce the acoustic discomfort.

- Implement engineering controls such as sound enclosures, barriers, or mufflers to reduce noise levels at the source.
- Provide workers with hearing protection equipment such as earplugs or earmuffs.
- Rotate workers to different tasks to minimize prolonged exposure to high noise levels.

It should be noted that without hearing protection, the **maximum time a CNC worker can be on shift is 2hrs** and the **maximum time a grinding worker is on shift is 2 minutes** according to calculations. Unless they will lose their hearing ability with time.

Issue: Poor lighting fixtures

Thavam motors mostly rely on natural lighting and they use bulbs only for CNC maching. Natural light levels can vary depending on factors such as time of day, weather conditions, and seasonal changes. This can lead to inconsistent lighting levels across the workspace, causing discomfort and difficulty in performing tasks.

Here are approximate lux levels for different times of the day in Sri Lanka: (Elvitigala, 22.04.2021)

Table 7.2: light intensity

Time	Approximate lux level on a normal day	Approximate lux level in rainy season
8 am – 10 am	20000	500
10 am – 12 pm	40000	1500
12 pm – 2 pm	30000	1000
2 pm – 4 pm	15000	400

Lighting calculation for CNC machine:

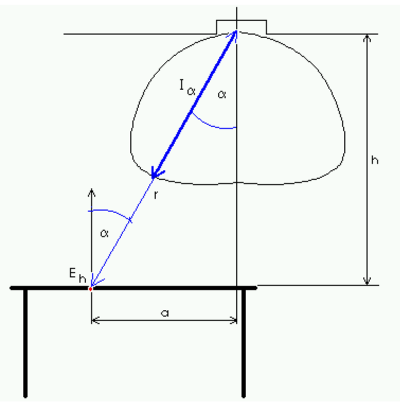
Lumens of bulb fitted above CNC machine = 4000lm

Intensity = 4000lm / sr = 318.3cd

h = 6 feet, a = 3 feet,

E = 318.3cd x cos(26.56) / 45 = 6.3 foot candles = 6.3 fc x 10.76 lux/fc

= 68.07 lux



$$E_h = \frac{I_\alpha}{r^2} \cdot \cos\alpha$$
$$= \frac{I_\alpha}{h^2} \cdot \cos^3\alpha$$

The necessary lighting level according to the IESNA standard is shown in the following table (24Pe).

The necessary lighting level according to the IESNA standard is shown in the following table (24Pe).

Table 7.3: machine area and light level

Machine	**Light level (lux)**
CNC Machines	750
Lathe Machines	500
3D Printers	350
Drilling Machines	750
Thread Cutting Machines	750
Grinding Machines	750

From the table of natural light levels and table of necessary standard light levels, it can be concluded that relying solely on natural light during rainy seasons is not sufficient.

The calculation of CNC machining light also illustrates that the lighting need is not fulfilled and they are working in very low light conditions which will cause eye strain and fatigue due to the effort required to see in low light conditions. This can lead to headaches, decreased productivity, and potential safety hazards.

Therefore following solutions should be considered for the machining operations that only depend on natural lighting.

- Need to install a lighting fixture with 45000lm to raise the lux level in your CNC machine work area to meet the recommended IESNA standards.
- Consider using artificial lighting with dimmers or occupancy sensors to maintain consistent standard lux levels during the rainy season.
- Install additional lighting fixtures to optimise the light level during low light conditions.

7.2 Develop and implement a new layout plan

1. Poor layout plans

The main work layout plan is shown in the following picture.

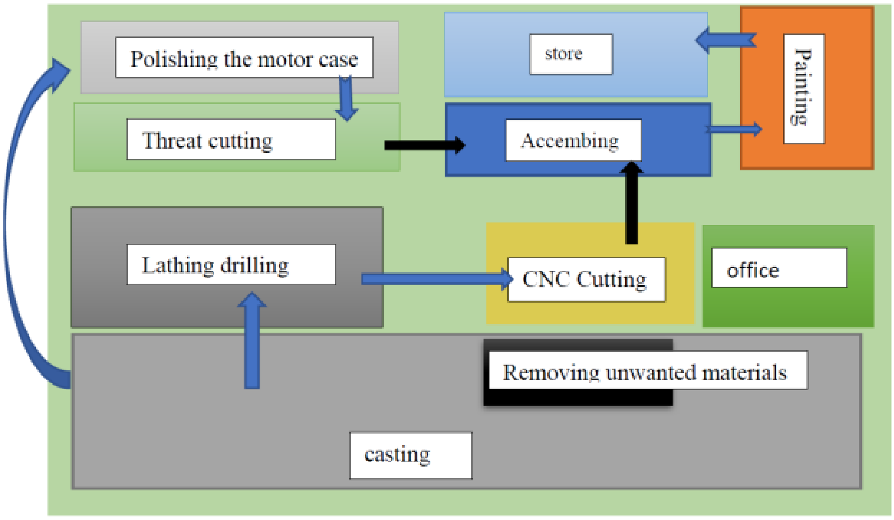


Figure 7.1: current layout

It can be seen that the distance between the polishing workstation and the casting station is too far and it increases the production time. Therefore, the layout can be changed to the following optimal way.

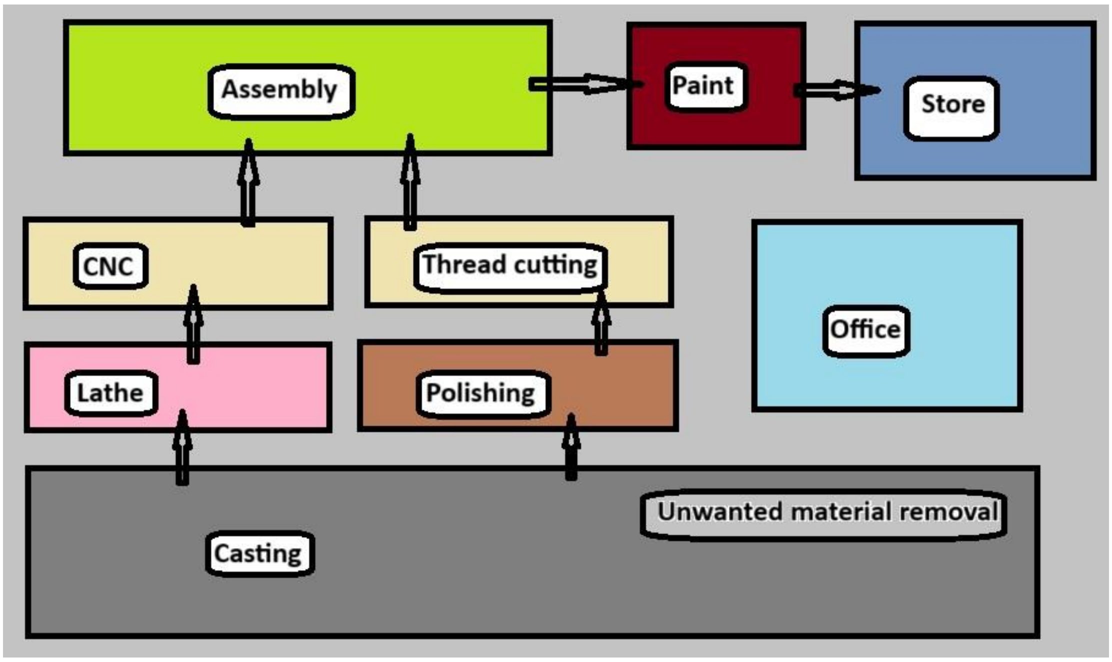


Figure 7.2: new layout

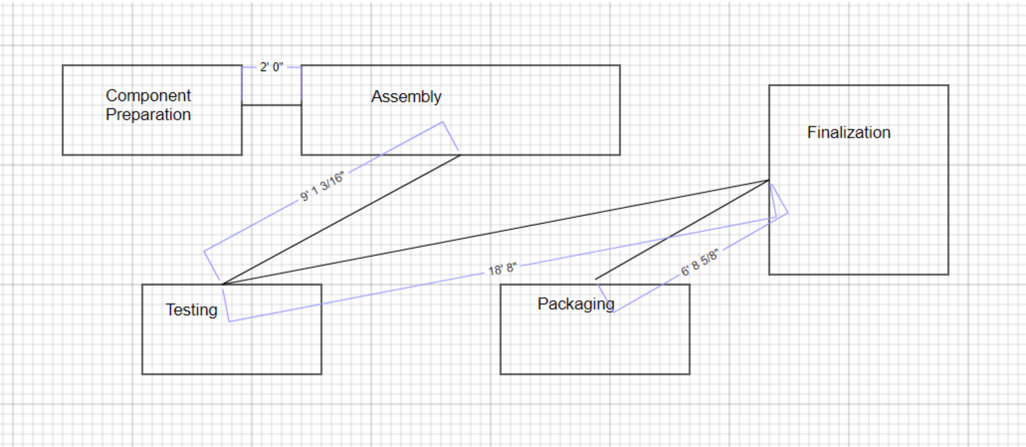
Moreover, a few small issues were found that reduced productivity in each working layout.

Assembly process:

In the current layout plan, the workstation for component preparation is located at one end of the assembly line, while the testing and adjustment area is situated at the opposite end. This layout forces workers to traverse the entire length of the assembly line multiple times, increasing their moving distance and wasting time.

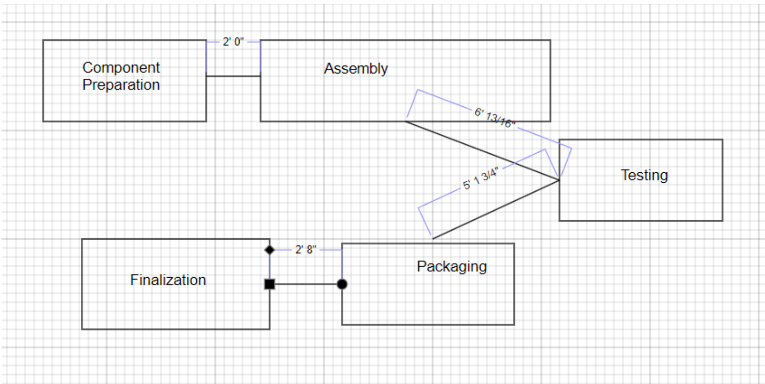
Assembly Process Steps:

1) Component Preparation
2) Assembly Sequence
3) Testing and Adjustment
4) Finalization
5) Packaging and Shipping



Here the average walking distance of a worker is 30.5 feet.

Solution: Rearrange the layout to minimize worker travel distance and optimize workflow.



After modification, the average walking distance of a worker is reduced to 16 feet.

7.3 Improving Quality control measures

quality management is a critical tool in a factory scenario. It should have structured systems, procedures and processes that guide all the activities in a manufacturing organisation for giving customer-satisfied products. These activities include establishing and executing quality planning, control, and policy. Collectively, they are known as Total Quality Management(TQM)[5].

Quality measures can be done to goods and services. At Thavam Motors, they offer water pumps and related products, along with after-sales service. They follows a way to manufacture the pump without knowing its performance and efficiency. They have a dealer in India who supports each way of their manufacturing process. Thavam Motors uses the pattern for the sand casting brought from India. There are some Indian workers as well who came to work here on a contract.

7.3.1 Dimension of the quality of Thavam Motors products,

- Performance
- Reliability and durability
- Safety
- Aesthetic

Performance

The performance test is very important in considering pump manufacturing. They have to ensure that their pumps are in a standard manner. Big manufacturing firms have large testing platforms and professional testing software to conduct flow, head, efficiency and performance tests of the finished pumps[6]. But, we don’t see such performance testing in Thavam motors.

Performance characteristic graph is essential for a manufacturer which helps the customers to choose the right pump for their application. Thavam motors do not have such a graph cause they don’t do any testing for their pump. They just follow the way of manufacturing how others do.

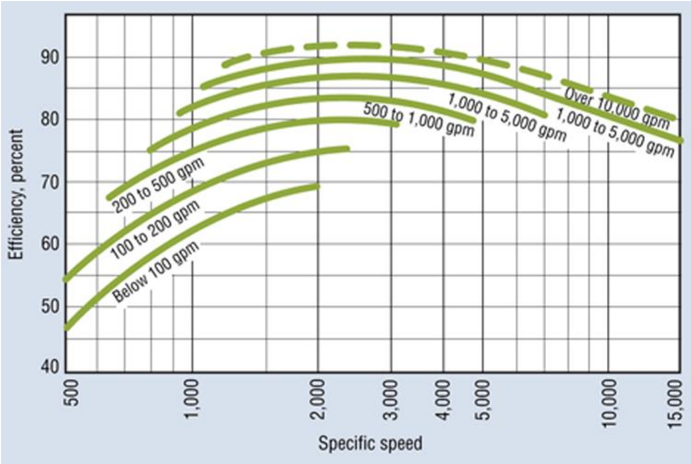


Figure 7.3: performance correcteristic curve.

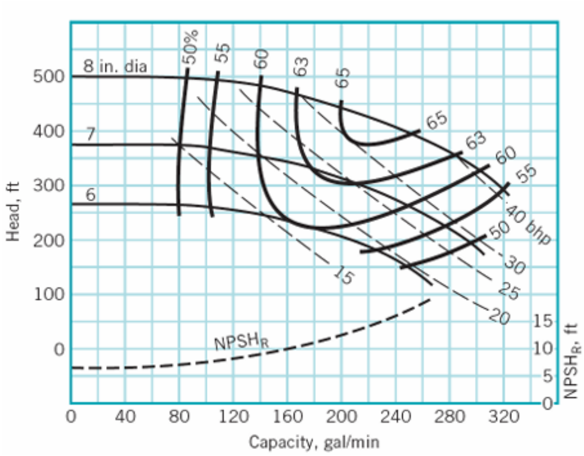


Figure 7.4

To plot this graph, there are some data requirements. they are,

- Flow rate (Q) in (m^3/h)
- Head (H) in (m)
- Efficiency (η) in (%)
- Power consumption (P) in (kW)

Unfortunately, we don’t get the opportunity to test and get these data in this firm. Using the graph, the manufacturer gives the best efficiency point (BEP) where the pump operates most efficiently.

In the customer, Pump selection is essential for appropriate applications. There are various equations to select the suitable pump.

HSYS=Static head + Pipe frictional losses + Component losses

$$H_{sys} = (Z_2 - Z_1) + \left(\lambda \frac{L}{D}\frac{V^2}{2g}\right)_{S+D} + \left(\sum k_i \frac{V^2}{2g}\right)_{S+D}$$

Hsys = Z+KQ2

$$N_S = \frac{\omega Q^{1/2}}{H^{3/4}}$$

ω − rpm of the pump

$H_{sys}=H_p$

$$\eta = {P_{out}}/{P_{in}} = {H_P}/{H_T} \qquad P_{in} = \frac{H_P \rho g Q}{\eta} \qquad P_{out} = H_P \rho g Q = \Delta P Q$$

Pump efficiency.

Here,

H- Head

Q- volume flow rate

Z- hight

P- power

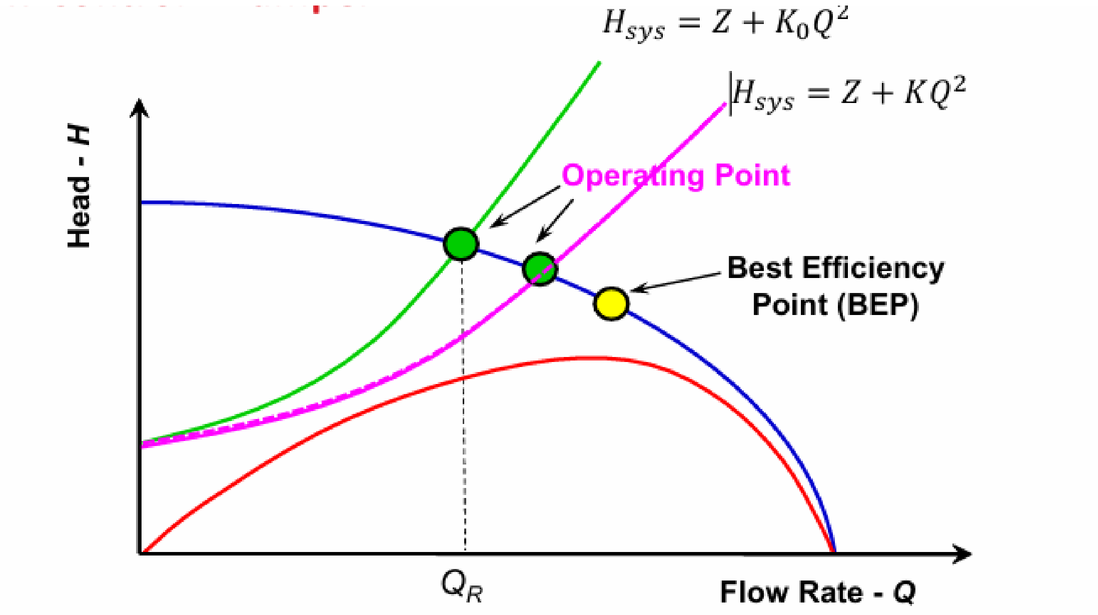


Figure 7.5 flow rate VS Head

Finally, the customer can select the suitable pump using these analysis with the help of the manufacturer performance characteristic graph.

Reliability and durability

In terms of reliability and durability, materials resistant to corrosion are chosen. For high corrosive environmental conditions such as coastal areas, white cast iron is selected. With the exception of the coil, each component is manufactured in-house. Local applications are considered when choosing materials.

The material selection is acceptable both for environmental reasons and from a cost perspective:

Motor shaft: white cast iron, Impeller: brass, Body: alloy steel

They maintain a commitment to providing a good warranty period for their products, with most items being offered with a one-year warranty.

Safety

Their motors deal with current water pumps while the water is conductive. In case of any current leakage to the body of the motor, it may kill lives. Thavam's group carefully handled this. They use a closed water-sealed pack for the circuit part. And there is a fuse which will cut off the current in any over-current situations.

Aesthetics

Thavam Motors considers the aesthetic view as well to reach more customers. They use significant paint for each categorized motor pump and other products.

Figure 7.6: thavam motors

7.3.2 Dimensions of quality of services,

Time and timelines

Customers can reach them on any working day for their services. They will take a maximum of five days to return the customer's products. This is a huge period as a motor pump is essential in the household.

Courtesy and Consistency

Due to the field visit, we observe that they properly treat the customers and provide services consistently. All of Them are very experienced and easily find out the issue with the product and predict the time to repair them.

Accessibility and convenience

Thavam Motors has a separate unit for the services after sales. there are five People working on repairing the water pumps and other products which have failed within the warranty period.

7.4 Work study.

A work study program is a management and monitoring service. While "work study" refers to a variety of approaches, method study and work measurement are specifically included. The use of methods to determine how long it takes a skilled worker to complete a task at a specific rate of work is known as work measurement. The investigation and any ineffective time related to it, as well as the following formulation of time requirements for the operation, are the main concerns of work measurement.

Performance rating

Westinghouse rating = Sum of ratings, i.e. rating of (Skill + Effort + Conditions + Consistency) as given in Westinghouse tables.

Rating Factor = 1 +/- Westinghouse Rating

Table 8.1 : Westinghouse Performance Rating Table

Factor → Grade ↓	Skill (1)	Effort (2)	Conditions (3)	Consistency (4)
Super (1)/Excessive(2)/ Ideal(3)/Perfect(4)	$A_1 = +0.15$ $A_2 = +0.13$	$A_1 = +0.13$ $A_2 = +0.12$	$A = +0.06$	$A = +0.04$
Excellent	$B_1 = +0.11$ $B_2 = +0.08$	$B_1 = +0.10$ $B_2 = +0.08$	$B = +0.04$	$B = +0.03$
Good	$C_1 = +0.06$ $C_2 = +0.03$	$C_1 = +0.05$ $C_2 = +0.02$	$C = 0.02$	$C = 0.01$
Average	D = 0.00	D = 0.00	$D = 0.00$	$D = 0.00$
Fair	$E_1 = -0.04$ $E_2 = -0.10$	$E_1 = -0.04$ $E_2 = -0.08$	$E = -0.03$	$E = -0.02$
Poor	$F_1 = -0.16$ $F_2 = -0.22$	$F_1 = -0.12$ $F_2 = -0.17$	$F = -0.07$	$F = -0.04$

Figure 7.7 Performance rating table

Job process we choose Casting for impeller and lathe operation for rotor of motor.

Casting

Thavam motors do casting in 2days in week, we measure the job process with stopwatch but due to limited time we only take one reading so accuracy results weren't great.

Here below we divided the job into elements.

Sample rating for melting.

Skill = 0.11

Effort = 0.10

Conditions = 0.02

Consistency = 0.01

Total = 0.11 +0.10+0.02+0.01 = 0.24

Rating factor = 1+0.24

=1.24

Table 7.4: process VS Taken time

Element No	Elements	Observed time	Rating
1	Melting	30mins	1.24
2	Mould filling	13.28mins	1.18
3	Solidification	45mins	1.16
4	Mould removal	7.04mins	1.18
5	polishing	13.947mins	1.16

For element 1: Normal time = observed time * rating factor

N = 30mins*1.24 = 37.2mins

Standard time = normal time * allowance factor

S = 37.2mins * 100/ (100-7) = 40mins

For element 2: Normal time = observed time * rating factor

N = 13.28mins* 1.18 = 15.67

Standard time = normal time * allowance factor

= 15.67*100/ (100-40) = 26.11mins

For element 3: Normal time = observed time * rating factor

N = 45mins*1.16 = 52.2mins

Standard time = normal time * allowance factor

= 52.2*100/(100-5) = 54.95mins

For element 4: Normal time = observed time * rating factor

N = 7.04mins*1.18 =8.3072

Standard time = normal time * allowance factor

= 8.3072*100/(100-7) = 8.93mins

For element 5: Normal time = observed time * rating factor

N = 13.947mins *1.16   = 16.17mins

Standard time = normal time * allowance factor

= 16.17mins*100/ (100-8)

= 17.58mins

From calculating the rating for the workers, all values were positive, indicating that employee efficiency is good. Therefore, we conclude that the current method works well for them, and no changes are suggested.

Standard time is crucial for creating realistic work schedules. It ensures that employees have enough time to complete tasks without undue pressure. With standard time calculations, we suggest incorporating allowances so that the casting process can be scheduled with these factors included. This will help to accurately determine the lead time for the product.

Pouring requires a significant allowance; therefore, it is better to add an extra worker, as there were only two workers handling it all day. By adding a worker, this time could be minimized.

Standard times can also be used to design fair and motivating incentive programs for workers, encouraging them to maintain a high level of productivity without compromising quality or safety.

Turing operation on lathe

Table 7.5

Element No	Element	Observed time	Rating
1	Job fixing in the 3 or 4 Jaw Chuck	10mins	1.19
2	Tool setting /centring	4min	1.12
3	Turning the job	17mins	1.16
4	Removing the job from chuck	4min	1.18

For element 1: Normal time = observed time * rating factor

N = 10mins*1.19 = 11.9mins

Standard time = normal time * allowance factor

= 11.9mins*100/ (100-5) = 12.52mins

For element 2: Normal time = observed time * rating factor

N = 4mins*1.12 = 4.48mins

Standard time = normal time * allowance factor

= 4.48mins*100/(100-5) = 4.71mins

For element 3: Normal time = observed time * rating factor

N = 17mins*1.16 = 19.72mins

Standard time = normal time * allowance factor

= 19.72*100/ (100-7) = 21.20

For element 4: Normal time = observed time * rating factor

N = 4mins*1.18 =4.72mins

Standard time = normal time * allowance factor

= 4.72mins*100/ (100-7) = 5.075mins

From the turning operations study, we found that all worker ratings were positive, indicating that the current system is effective and accurate. For standard time calculations, we suggest incorporating a standing allowance for workers. By including this allowance, we can predict accurate lead times and develop more realistic work schedules. This approach will help ensure that employees have sufficient time to complete tasks without undue pressure, ultimately encouraging them to maintain a high level of productivity.

7.5 Process simulation.

Thavam Motors follows a workshop process strategy rather than a production line approach. Simulating all processes in software can be challenging. For the first simulation, we'll focus on the production of a specific type of water pump. To simplify the simulation,

we've made the following assumptions:

- The failure rate of machinery such as lathes and CNC machines is zero.
- Certain processes, including casting, painting, and testing, occur weekly with sufficient resources and are not included in the simulations.
- Components like foot valves and pump mountings are produced separately and are not part of the simulation process.
- Each assembly section is allocated to a specific type of pump.

Process details

Figure 7.8: thavam motors parts

Table 7.6

Processing Time(min)		
Parts	Lathe	CNC
Impeller	4.20	7.10
Pump Housing	5.30	6.30
Front and End Cap	3.10	-

Middle Housing(grinding)	15	

Simulated production line

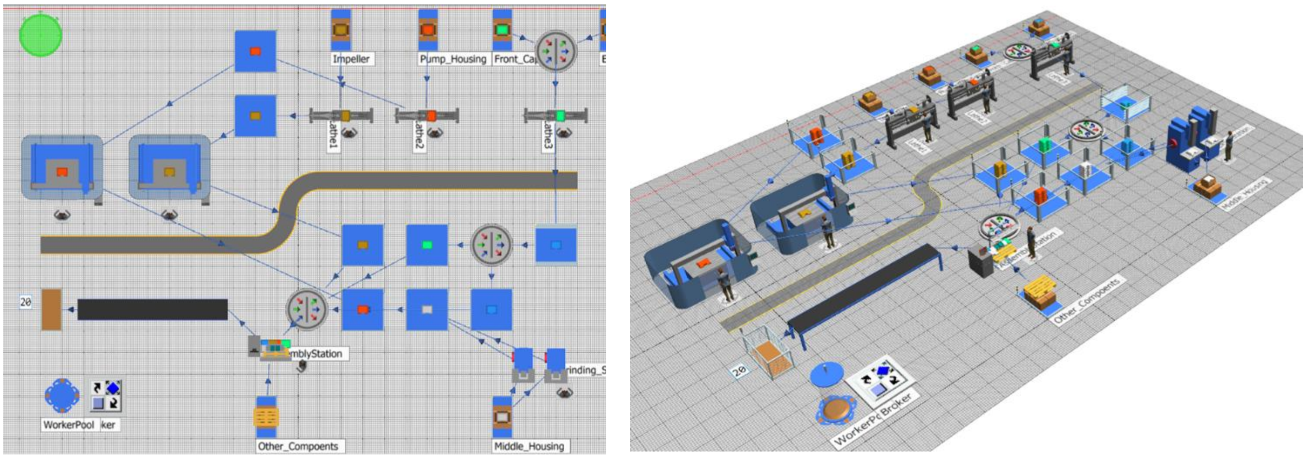
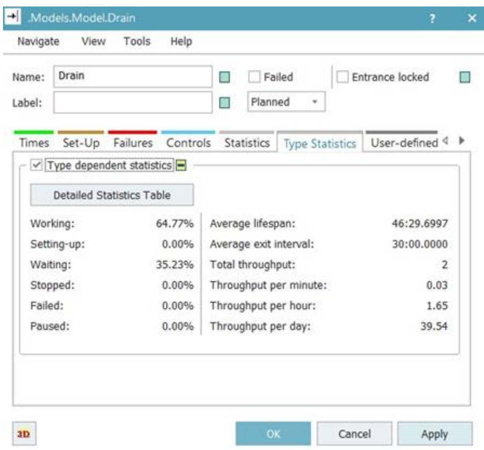
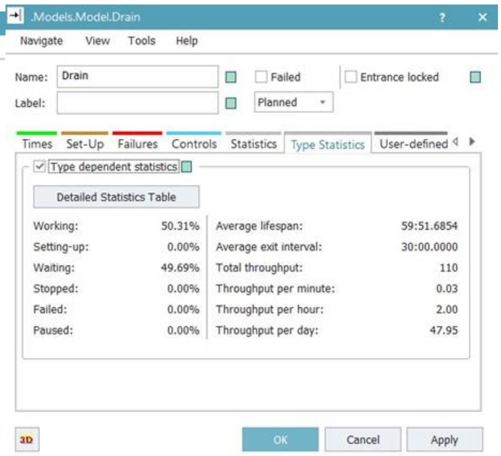


Figure 7.9: production line





8 DISCUSSION AND CONCLUSION

8.1 Introduction

Thavam motor is an initial stage of the industry. Still, there are no professionals. It is running with some help of foreign suppliers and experienced staffs. There are lots of improvements are required to take place to make it as a professional firm. We identified each area that require the improvement and provided solutions.

8.2 Discussion about your findings

Still in thavam motors, there are no proper lighting and noise control systems. It will affect the efficiency of the workers. Through this report, we analyse the data we collect from the field and provide an Audit to upgrade lighting fixtures.

Thavam motors still don't have any performance characteristic curve for their pumps which is essential to a customer choose it according to the requirement. To plot that graph, we required some data which is coming from the testing. But unfortunately, we don't get the chance to do the testing. However, we include the method to plot the graph in this report.

Result of simulation the current throughput per hour stands at 1.65 units. Over a week (assuming 8-hour workdays and 6 working days), this translates to approximately 80 pumps produced. Interestingly, this output aligns closely with the real production of a specific pump type, which amounts to 75 pumps.

The grinding and polishing process emerges as the bottleneck in our production line. It limits the overall throughput and prevents us from achieving higher production levels.

To address the bottleneck, we propose introducing an extra station. By doing so, the throughput per hour can increase to nearly 2 units. Consequently, weekly production could reach approximately 96 pumps.

In summary, identifying bottlenecks and strategically adding stations can significantly enhance production efficiency. Manufacturers should continuously evaluate their processes to maintain optimal throughput.

From the turning operations study, we found that all worker ratings were positive, indicating that the current system is effective and accurate. For standard time calculations, we suggest incorporating a standing allowance for workers. Pouring in casting process requires a significant allowance; therefore, it is better to add an extra worker, as there were only two workers handling it all day. By adding a worker, this time could be minimized.

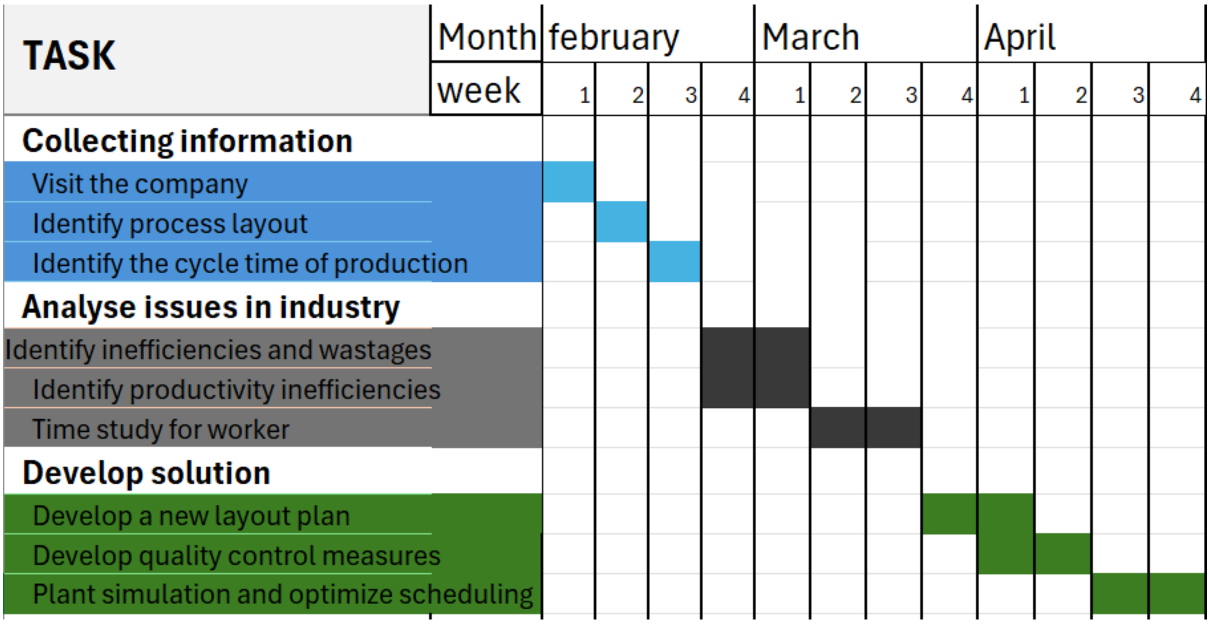
8.3 Expected budget

As it is an initial state of an organization, there are lots of things to change. Due to the varying market prices, we couldn't estimate the proper budget.

8.4 Limitations

- Due to the economic state of the country and high expenses, the management doesn’t like to make changes in layout and other changes in the factory design.
- It will take much time to make implement the improvement as this whole process is big.
- There is no enough budget in the firm to implement all these ideas at a time.
- It’s hard to teach the workers as There are no professionals.

9 FUTURE WORK



this is the way we came through. But still there are lots of to pass. Under each objectives, there are certain amount of implementations. It all will take money and cost. for the next step, we are going to submit this report to the organization and suggest to them to take action to some immediately possible problems.

- Increase the lighting in the workshop to improve the worker’s efficiency.
- Do a test to plot the performance characteristic graph which is essential for a pump manufacturer.
- Do the work-study and identify the quality workers and others. It will help to encourage them.

Later, they can improve the layout plan and machine arrangement, as this process may interrupt the factory operations and result in higher costs in terms of time and money

10 REFERENCES

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