Manual Lawn Mower

Group 6

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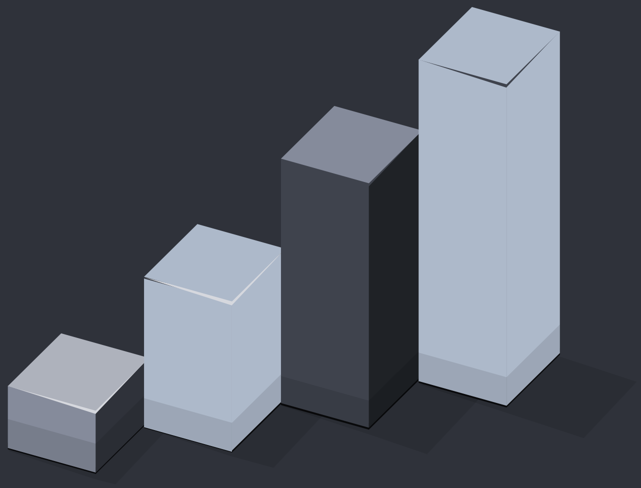
Product Specification

- Grass can be mowed - 1.5-2.5 inch height
- Cover 18 inch width at one drive
- Maximum coverage – 700 m^2/hr
- Maximum Speed – 1.5km/hr

Why our product ?



1.Upgrade of existing machines

2. Leverage of existing power sources

3. Affordable Price

4.Have high potential use of time

5.Totally eco friendly

6. Reduce cost, labor and saves time


Customer
Survey

Survey Area

MIST

Savar Golf Club

Glimpse of Customer Survey

27%

Who can be the customers and users?

Professionals

63%

What you normally use for mowing?

Normal Blade with Bare Hand

60%

Which type of mower is preferable?

Manual

53%

What is the benefit of using bicycle?

No electric power

Glimpse of Customer Survey

50%

How many hours can you work with this lawnmower at a time?

2 Hour or more

83%

If you get lawn mower which can easily be operated by single people, would it help?

Yes

43%

How many workers work regularly to mow a field?

6-7 person

43%

What should be the price range?

Less than 10000

Customer's Requirements

Efficiency

Price

Tool life

Flexibility

Easy to use

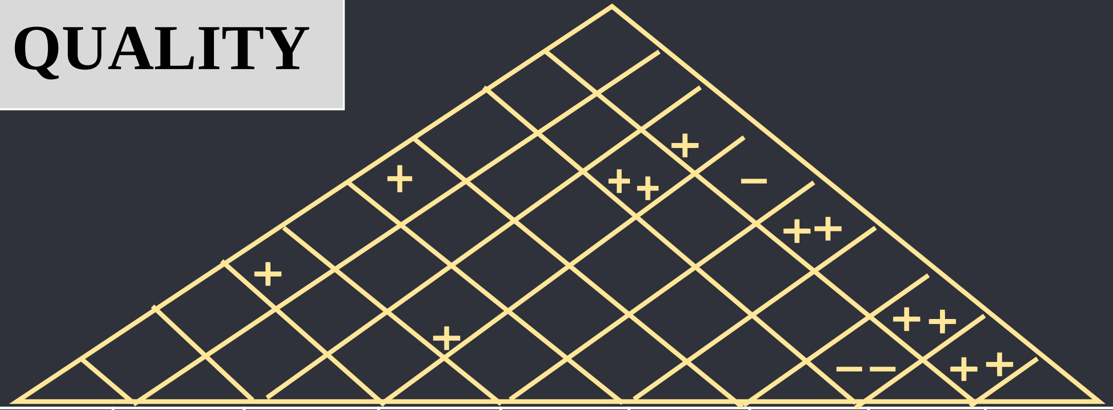
Appearance

Quality Functional Development

Quality Function Deployment (QFD)

- Define customer requirements
- Convert them into detailed engineering specification
- Plans to produce the products that fulfill those requirements

HOUSE OF QUALITY



Strong Positive	+ +
Positive	+
Negative	–
Strong Negative	– –

Symbol Score ■ – Strong (9) □ – Moderate (3) ♦ - Weak (1)	Bicycle Mechanism	Environmental Benefit	Cutting Speed	Ergonomics	Weight & Material	Gear , Chain	Warranty	Cutting Blade	Operational & Fixed Cost	Importance	We Today	Target In Future	Improvement Ration	Sales Point	Scores	Percentage
Time Saving	□		■							7	7	9	1.3	1.3	11.8	11
Portability	♦			□	■				■	6	7	7	1.0	1.1	6.6	6
Tool Life			□				■	■	■	9	6	9	1.5	1.3	17.6	16
Easy To Use	□			□		■	♦			10	7	8	1.2	1.5	18	17
Functionality	□		□			■	♦	■		8	6	8	1.3	1.3	13.5	13
Safety			□	□				■		7	5	7	1.4	1.1	10.8	10
Eco Friendly	♦	■								5	7	9	1.3	1.4	9.1	8
Low Cost				□	■		□	■		7	6	8	1.3	1.3	11.8	11
Easy To Maintain			♦			□		□		7	7	8	1.2	1.0	8.4	8
Score (Sum∑=1891)	137	72	224	132	153	294	207	474	198					Sum	107.6	
Percent Score (100)	7	4	12	7	8	15	11	25	11							

Relationship between customer requirements and technical requirements

Customer requirement	Engineering requirement	Relation	Explanation
Time saving	1. Cutting speed.	Strong	The more the cutting speed the less the time required.
	2. Bicycle mechanism	Moderate	The force is given to the paddle has moderate impact on horizontal movement.
Portability	1. Weight, material.	Strong	The less the weight, the more easy to shift.
	2. Bicycle mechanism.	Weak	The size of bicycle has less impact on portability.
	3. Ergonomics.	Moderate	The more ergonomics is applied, the more easily to port.
	4. Fixed cost.	Strong	Portability will increase the fixed cost.
Tool life	1. Cutting blade.	Strong	The more tool life increases, the quality of cutting blade also increases.
	2. Cutting speed.	Moderate	The more the cutting speed increases, the tool life decreases.
	3. Warranty.	Strong	When warranty increases the tool life will also be extended.
	4. Fixed cost.	Strong	Any improvement or increased property in the tool increases its life therefore the fixed cost is also increased.

Relationship between customer requirements and technical requirements

Customer requirement	Engineering requirement	Relation	Explanation
Ease to use	1. Bicycle mechanism.	Moderate	Bicycle makes it easy to operate.
	2. Gear chain.	Strong	The more the force is given through the gear chain the more the efficiency is.
	3. Ergonomics.	Moderate	It adds comfort on the customer side.
	4. Warranty.	Weak	The increasing of usability decreases the warranty.
Function ability	1. Bicycle mechanism.	Moderate	Bicycle mechanism makes it easy for function.
	2. Cutting speed.	Moderate	Cutting speed controls the function ability.
	3. Gear chain.	Strong	The more the force is transferred through the gear the more smoothly the product function.
	4. Cutting blade.	Strong	The sharper the blade is the more smoothly the product works.
Safety	1.Cutting blade	Strong	Blade can be dangerous if it is not used properly.
	2. Cutting speed	Moderate	Has moderate impact.
	3. Ergonomics	Moderate	Ergonomics is also applied for safe using.
Eco friendly	1. Environment benefits.	Strong	There is no use of fossil fuel.
	2. Bicycle mechanism.	Weak	This mechanism has no bad effect on environment.

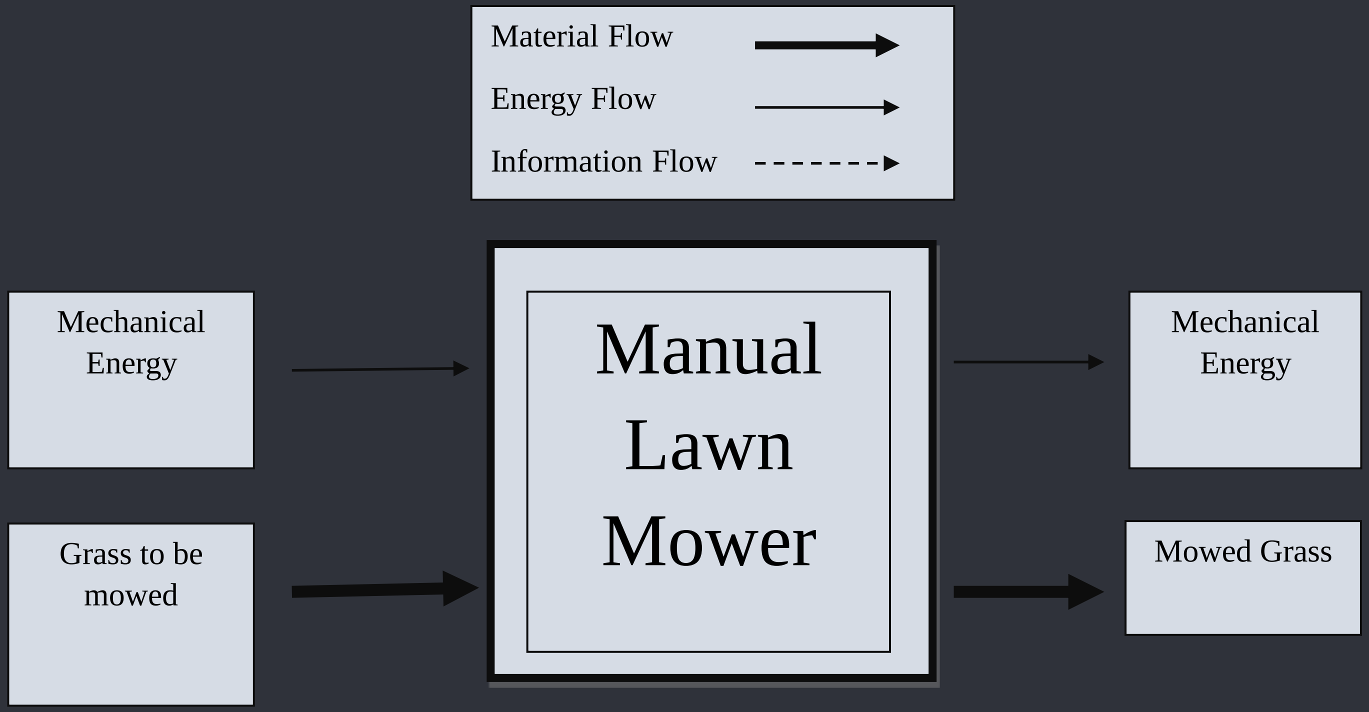
Relationship between customer requirements and technical requirements

Customer requirement	Engineering requirement	Relation	Explanation
Low cost	1. Ergonomics.	Moderate	Changes in ergonomics will bring moderate change in cost.
	2. Weight, material.	Strong	Increasing the quality of material will also increase the cost.
	3. Warranty.	Moderate	Cost varies moderately with warranty.
	4. Cutting blade.	Strong	High functioned blade increases the cost.
Easy to maintain	1. Cutting speed.	Weak	The increasing cutting speed has less impact on maintenance.
	2. Gear chain.	Moderate	To make the best use of gear chain maintenance is required.
	3. Cutting blade.	Strong	The more the cutting blade is used the more maintenance is required.

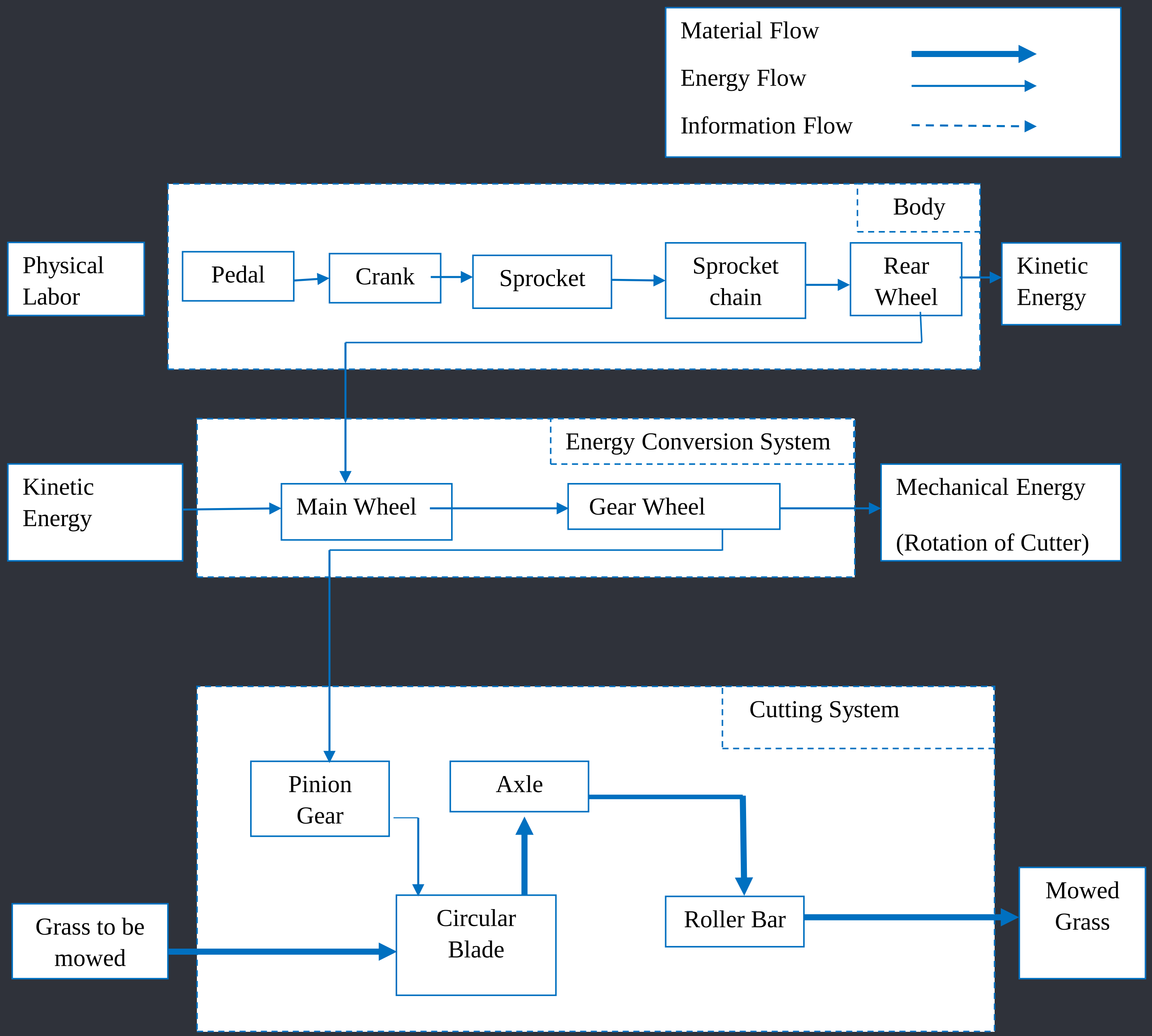
Functional Decomposition

Functional Decomposition

Black Box Model of Functional Decomposition



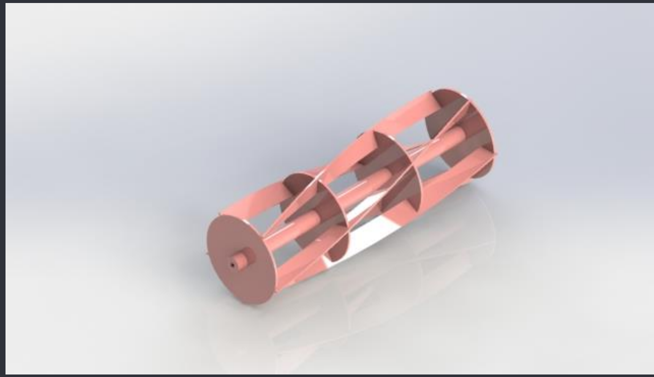
Cluster Function Structure for Manual Lawn Mower

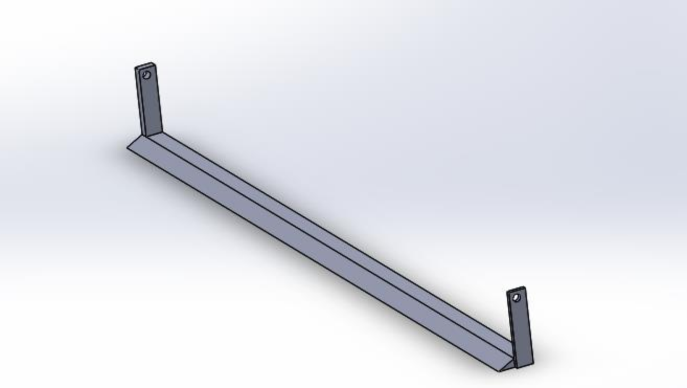


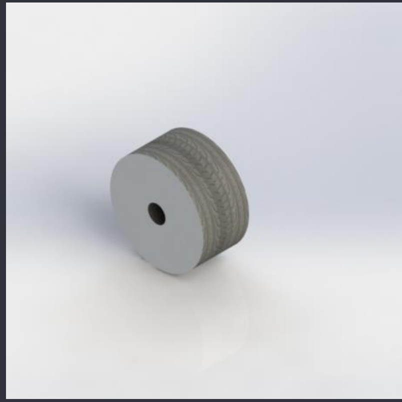
Design

Design Analysis

Part Designed by SolidWorks


Circular Blade


Axle


Roller


Roller Bar


Side Bar

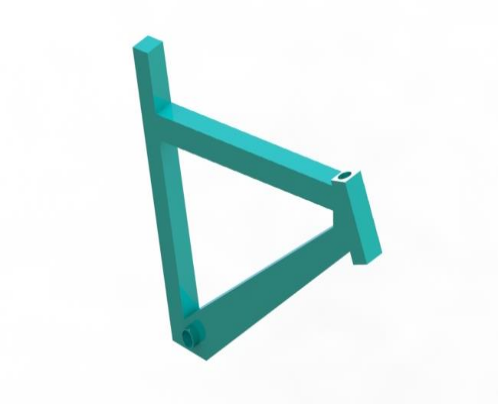

Front Link


Wheel Shaft

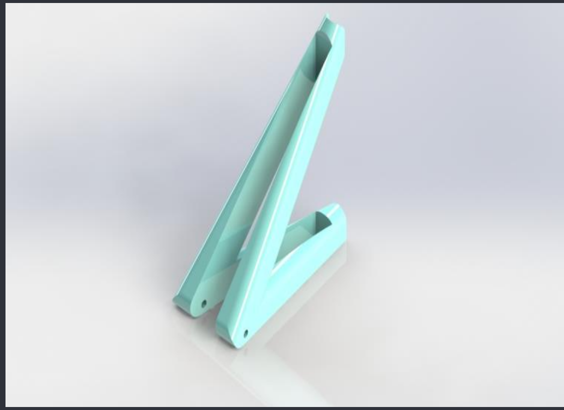

Mower Wheel

Design Analysis

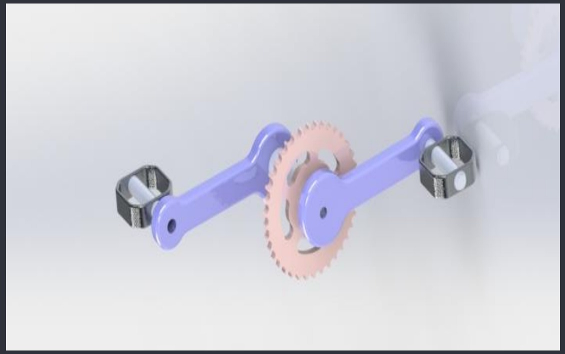
Part Designed by SolidWorks



Frame 1



Frame 2

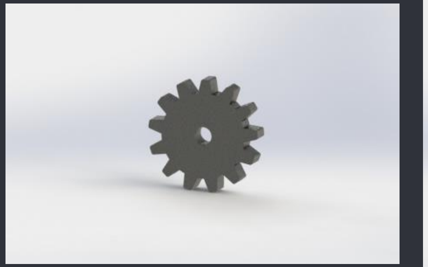


Pedal

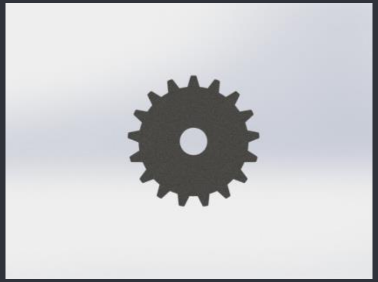
Handle

Rear Wheel

Handle grip

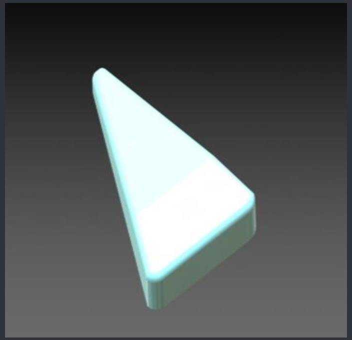


Pinion Gear



Wheel gear

Sprocket



Seat

Design Analysis

Final Assembly in SolidWorks

Final Product

Final Product

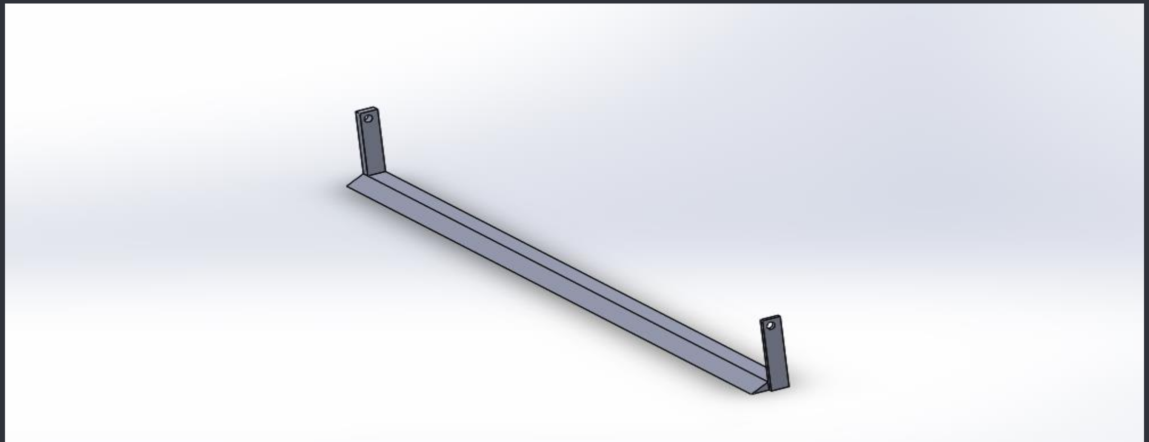
Front View

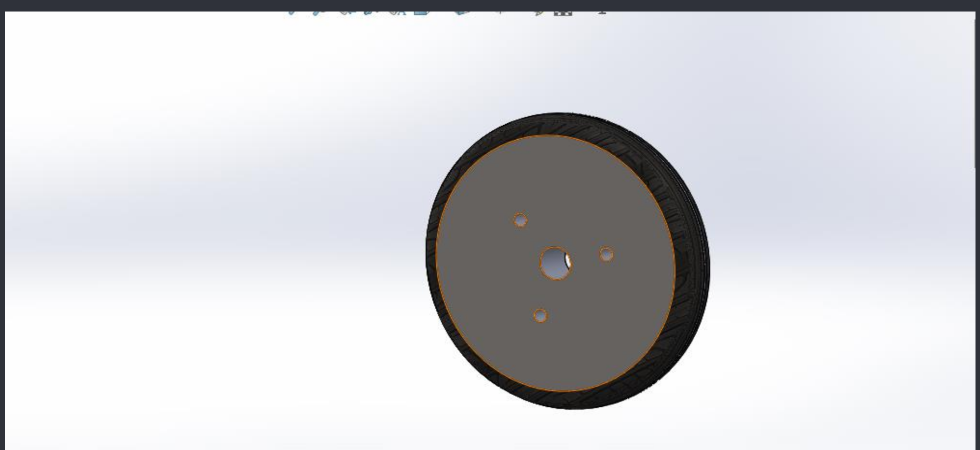
Top View

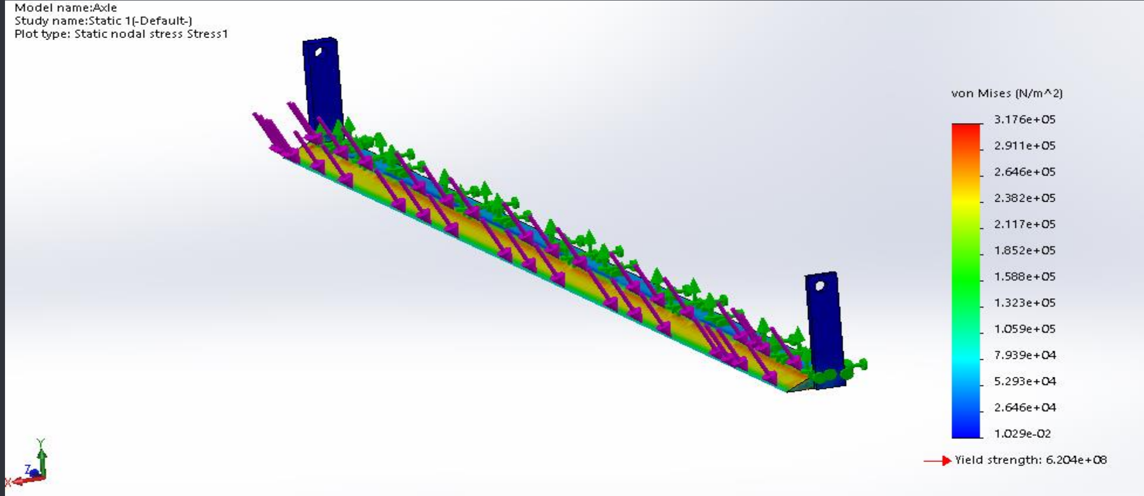
Side View

Stress Analysis

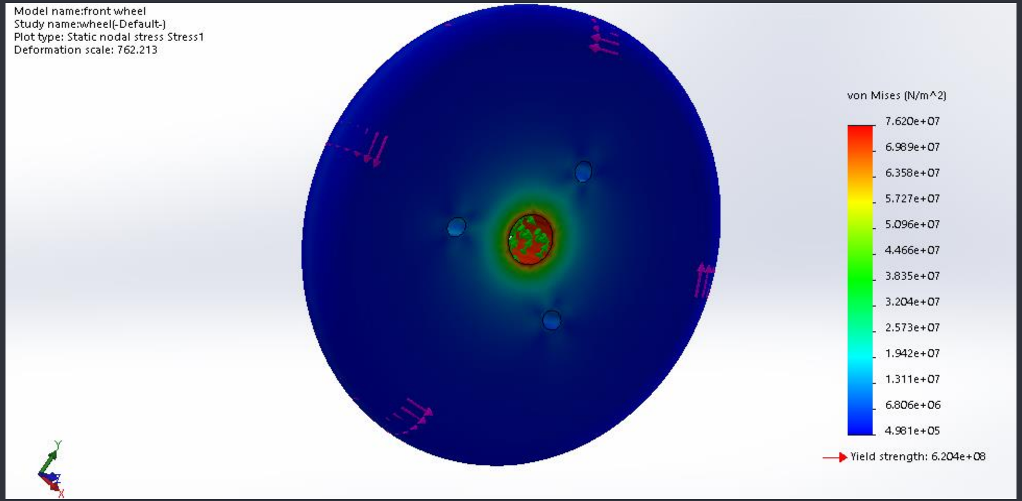
Stress Analysis on Axle and Mower Wheel





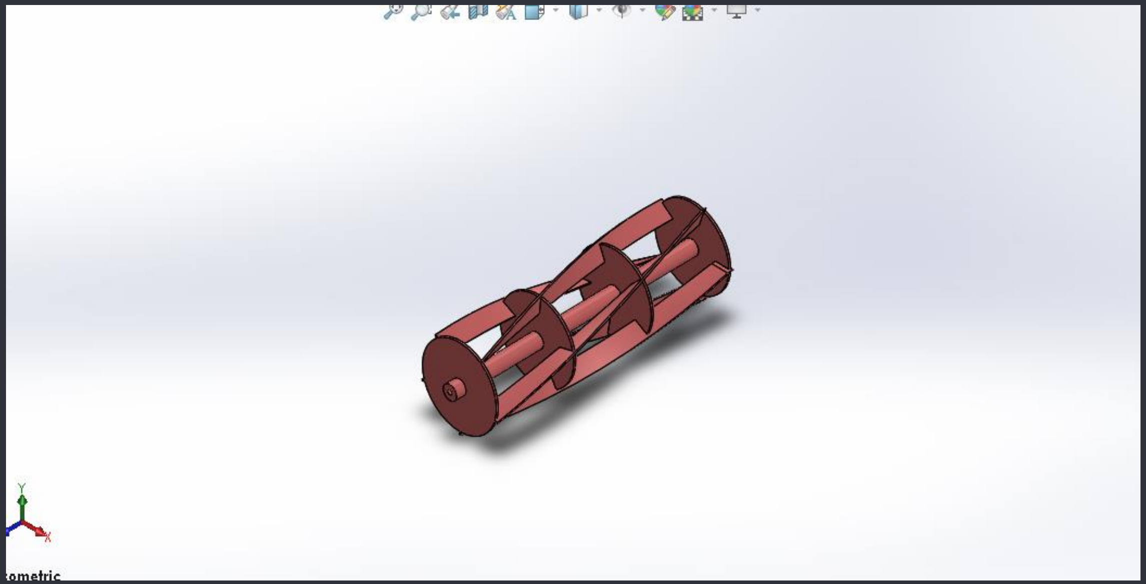


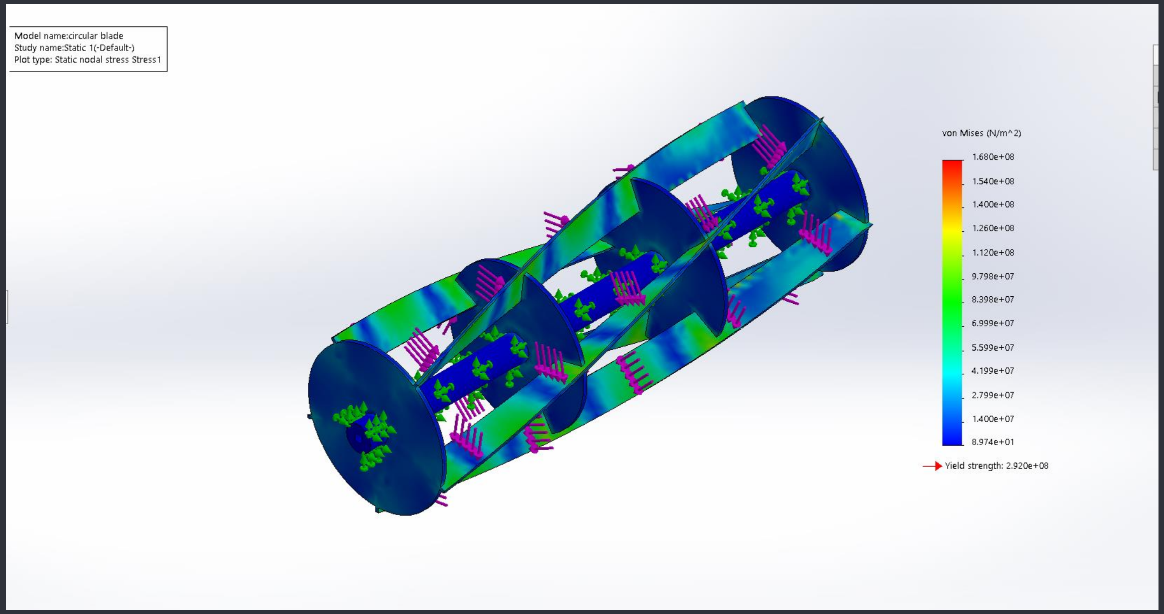
Force applied 200
Yield strength (6.204e+08)
Maximum stress (3.176e+05)



Force applied 600 N
Yield strength (6.204e+08)
Maximum stress (7.620e+07)

Stress Analysis on Circular Blade





Force applied 170 N
Yield strength (2.920e+08)
Maximum stress (1.68e+08)


Material Selection

For Material Selection Process We Used Digital Logic Gate Method

Material Selection For Circular Blade :

Selection Criteria	Number of positive decisions ,N=n(n-1)/2=6(6-1)/2=15															Positive Direction	Relative Emphasis Co-efficient (α)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Cost	0	0	0	1	1											2	.133
Strength	1					0	1	0	1							3	.200
Availability		1				1				1	0	0				3	.200
Shear Modulus			1				0			0			0	0		1	.066
Functionality				0				1			1		1		1	4	.266
Hardness					0				0			1		1	0	2	.133
	Total number of positive decisions															15	1

Calculation of Performance Index

Selection Criteria	Weighting factor (α)	Mild Steel		High Speed Steel	
		Scaled property ,(β)	Weighted score,(αβ)	Scaled property, (β)	Weighted score,(α β)
Cost	.133	100	13.33	75	9.98
Strength	.200	12.54	2.50	100	20.00
Availability	.200	100	20.00	60	12.00
Shear Modulus	.066	81.26	5.363	100	6.60
Functionality	.266	100	26.6	75	19.95
Hardness	.133	100	13.3	91.54	12.17
Material performance index, γ			81.093		80.7

Material Properties

Property	Mild steel	High Speed steel
Compressive Strength (N/m^2)	407.7×10^{6}	3250×10^{6}
Shear Modulus (N/m^2)	7.72×10^{10}	9.5×10^{10}
Rockwell Hardness (c)	71	65

Numerical value (rating) for cost, availability and functionality

Criteria	Mild Steel	High Speed Steel
Cost	3	5
Availability	5	3
Functionality	4	3

Very High	**5**
High	4
Medium	3
Low	2
Poor	1

Formula Used

For goals: Compressive Strength, Availability, Functionality, Shear modulus and Hardness–

$$\text{Scaled Property, } \beta = \frac{\textit{Numerical value of property}}{\textit{Maximum value of list}} \times 100$$

For goals: Cost –

$$\text{Scaled Property, } \beta = \frac{\textit{Minimum value of list}}{\textit{Numerical value of property}} \times 100$$

After calculation we selected Mild Steel for circular blade

By Same Method We Selected Mild Steel For Axle, Shaft, Front Link, Wheel Shaft, Pinion Gear and Wheel Gear.

Manufacturing Process

Sheet Cutting

Milling

Nut Bolt

Welding

Turning

Drilling

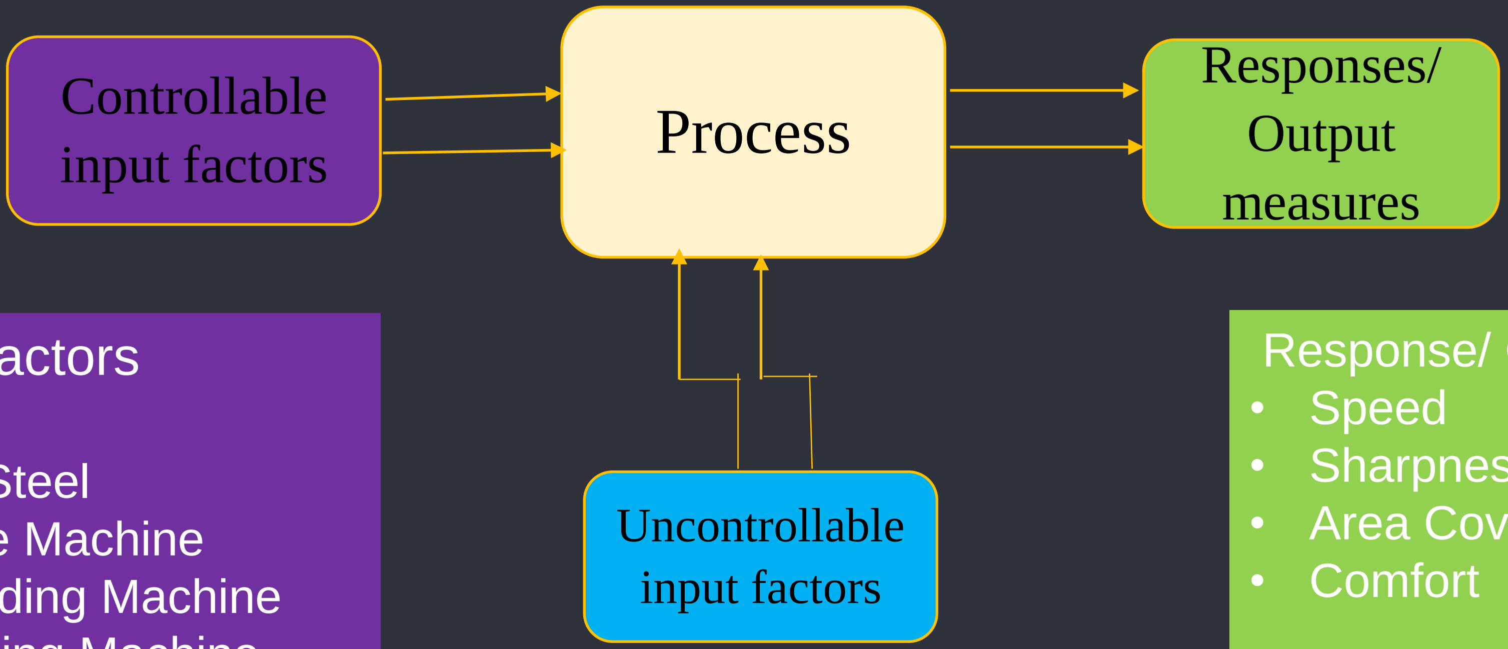
Grinding

Facing

Manufacturing Process Determined by “The relative importance of goals using digital logic method”

Part	Process
Circular Blade, Axle, Front Link	Sheet Cutting, Welding Machining, Grinding
Roller Bar, Wheel Shaft, Front Shaft	Turning, Facing
Wheel gear and Pinion gear	Milling, Facing
Joining Process	Arc Welding
Temporary Joining	Nutt- Bolt
Finishing	Non-precision grinding and polishing
Coloring	Spray


Design of
Experiment
(DOE)



Controllable Factors

- Type of mild Steel
- Model of lathe Machine
- Model of Grinding Machine
- Temp of Welding Machine
- Number of Gear
- Size of Axle
- Time of production
- Type of bicycle
- Diameter of wheel

Uncontrollable Factors

- Twisting Operation of Blade
- Labor

Response/ Output

- Speed
- Sharpness of Blade
- Area Coverage
- Comfort

Levels

- Cheap or costly
- Quantity of weld temperature
- Large or small
- Measurement of time
- Model number of equipment etc.

Software Approach

↓	C1	C2	C3	C4	C5-T	C6-T
	StdOrder	RunOrder	CenterPt	Blocks	Mild steel	Axle
1	2	1	1	1	costly	small
2	11	2	1	1	cheap	large
3	4	3	1	1	costly	large
4	3	4	1	1	cheap	large
5	1	5	1	1	cheap	small
6	12	6	1	1	costly	large
7	10	7	1	1	costly	small
8	7	8	1	1	cheap	large
9	6	9	1	1	costly	small
10	8	10	1	1	costly	large
11	5	11	1	1	cheap	small
12	9	12	1	1	cheap	small

Factors: 2 Base Design: 2, 4

↓	C1	C2	C3	C4	C5-T	C6-T	C7-T
	StdOrder	RunOrder	CenterPt	Blocks	Mild steel	Axle	Sharpness of blade
1	2	1	1	1	costly	small	12
2	11	2	1	1	cheap	large	12.5
3	4	3	1	1	costly	large	14
4	3	4	1	1	cheap	large	13
5	1	5	1	1	cheap	small	14.5
6	12	6	1	1	costly	large	12.8
7	10	7	1	1	costly	small	15
8	7	8	1	1	cheap	large	14.6
9	6	9	1	1	costly	small	13.4
10	8	10	1	1	costly	large	12.4
11	5	11	1	1	cheap	small	13
12	9	12	1	1	cheap	small	12.9

Software Approach

Factorial Design

Full Factorial Design

Design Summary

Factors:	2	Base Design:	2, 4
Runs:	12	Replicates:	3
Blocks:	1	Center pts (total):	0

All terms are free from aliasing.

Design Table (randomized)

Run	Blk	A	B
1	1	+	-
2	1	-	+
3	1	+	+
4	1	-	+
5	1	-	-
6	1	+	+
7	1	+	-
8	1	-	+
9	1	+	-
10	1	+	+
11	1	-	-
12	1	-	-

Factorial Regression

Factorial Regression: Sharpness of blade versus Mild steel, Ax

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	3	2.6158	0.87194	0.92	0.475
Linear	2	2.0083	1.00417	1.06	0.392
Mild steel	1	0.0075	0.00750	0.01	0.931
Axle	1	2.0008	2.00083	2.10	0.185
2-Way Interactions	1	0.6075	0.60750	0.64	0.447
Mild steel*Axle	1	0.6075	0.60750	0.64	0.447
Error	8	7.6133	0.95167		
Total	11	10.2292			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.975534	25.57%	0.00%	0.00%

Coded Coefficients

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		13.342	0.282	47.38	0.000	
Mild steel	0.050	0.025	0.282	0.09	0.931	1.00
Axle	0.817	0.408	0.282	1.45	0.185	1.00

Regression Equation

Regression Equation in Uncoded Units

Sharpness of blade = 13.342 + 0.025 Mild steel + 0.408 Axle + 0.225 Mild steel*Axle

Alias Structure

Factor	Name
A	Mild steel
B	Axle

Aliases
I
A
B
AB

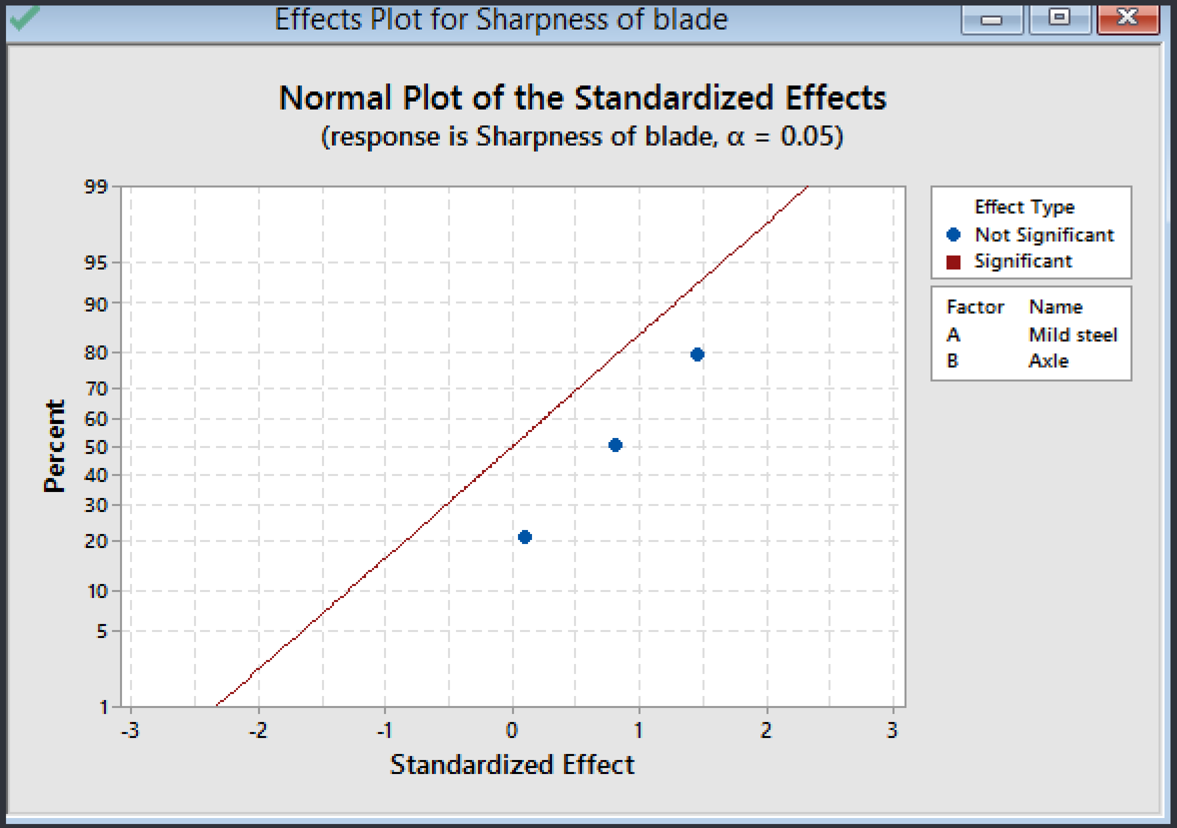
Effects Plot for Sharpness of blade

Effects Pareto for Sharpness of blade

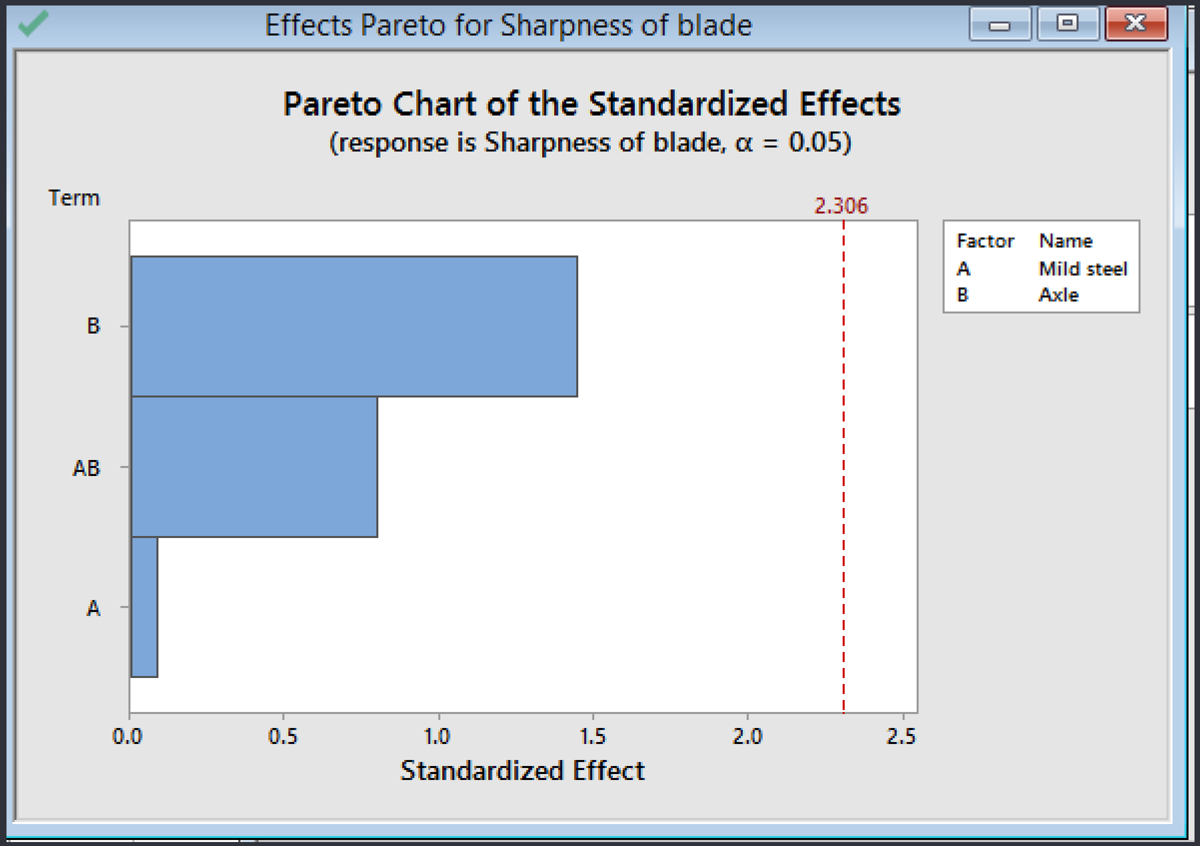
Residual Plots for Sharpness of blade

Software Approach

Normal Plot

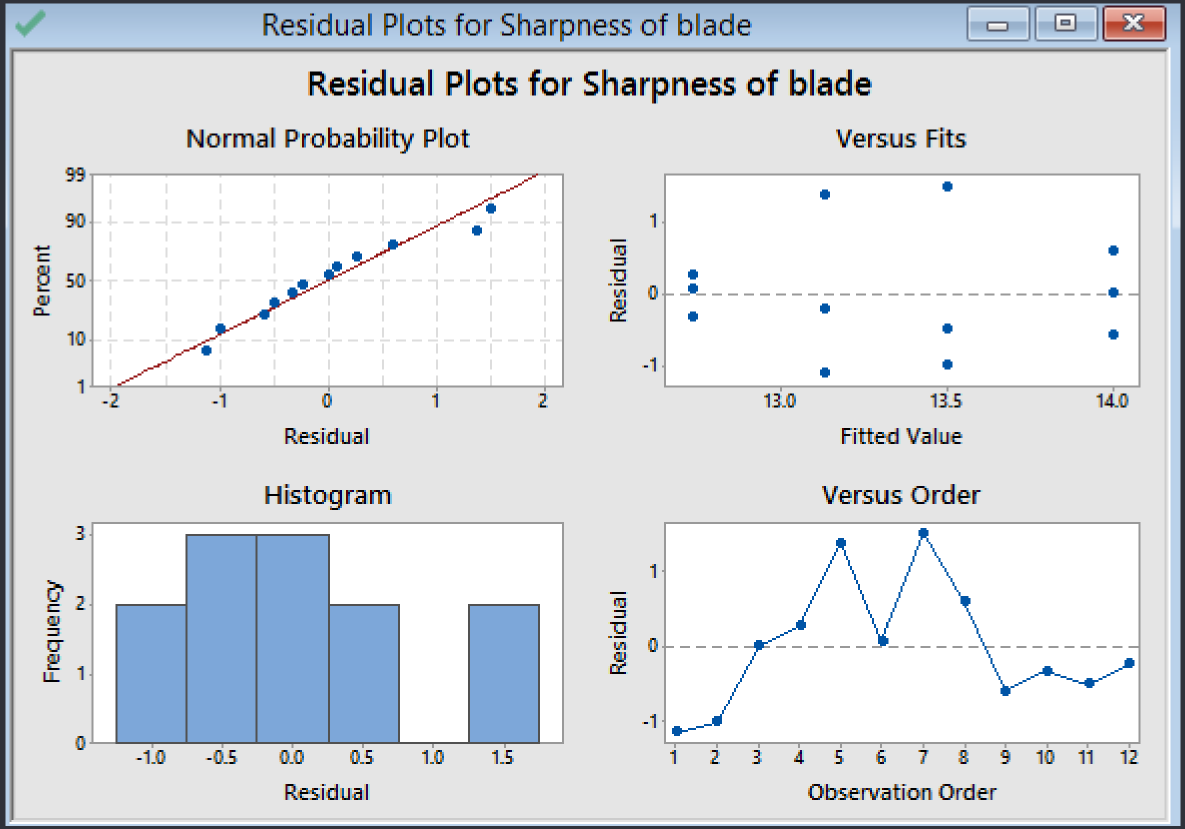


Pareto Chart

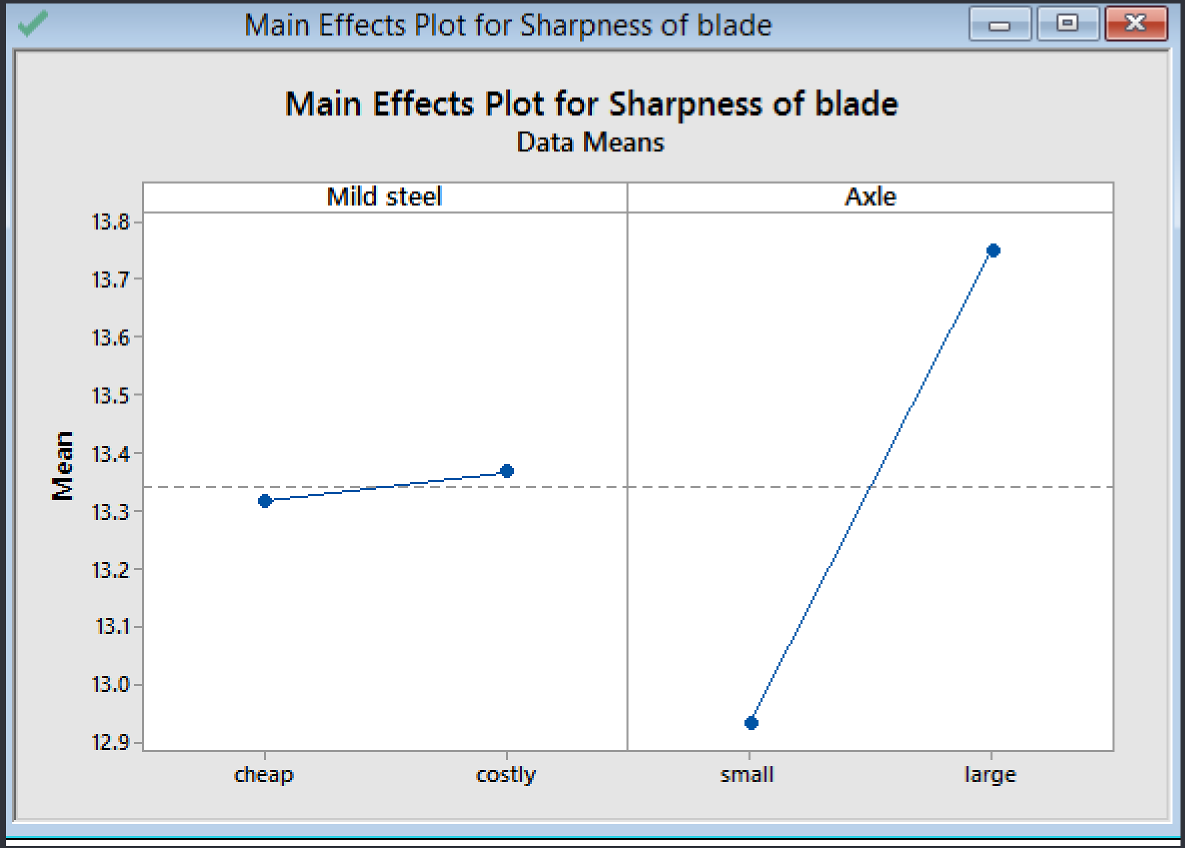


Software Approach

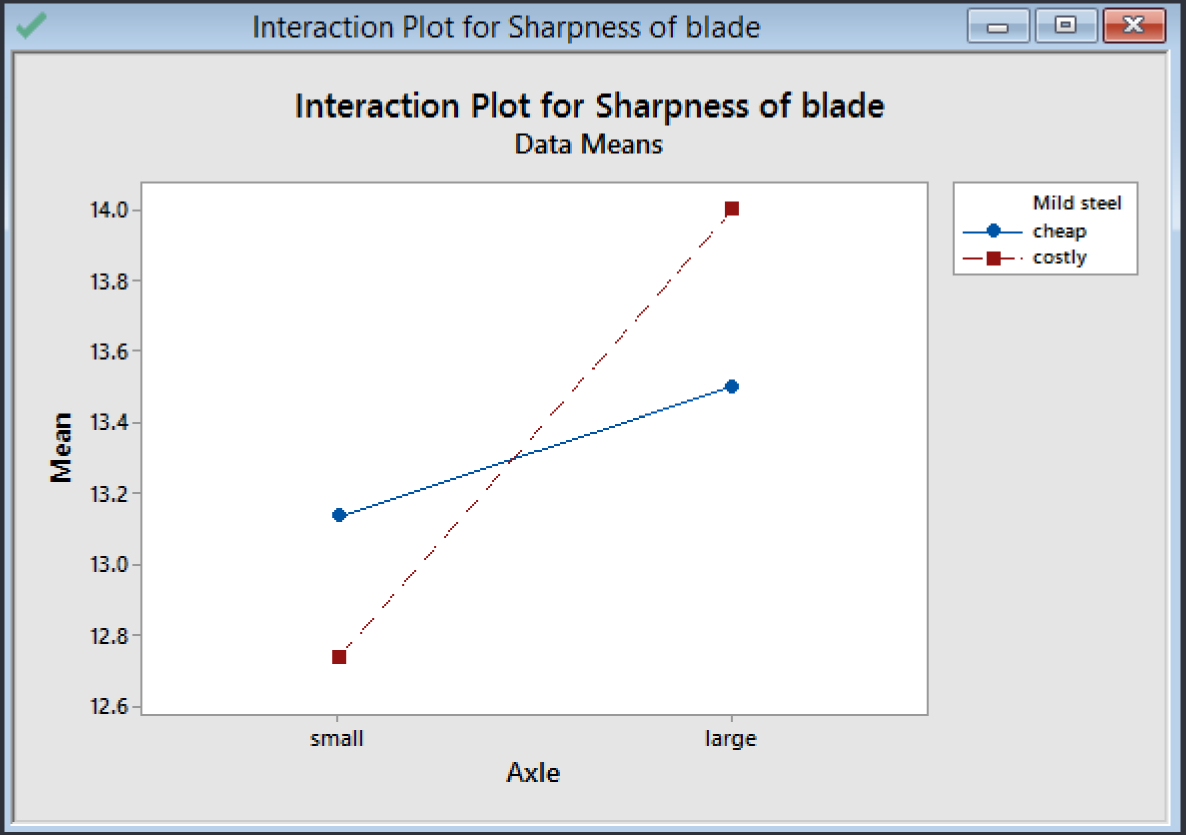
Residual Plots



Main Effects Plot



Software Approach

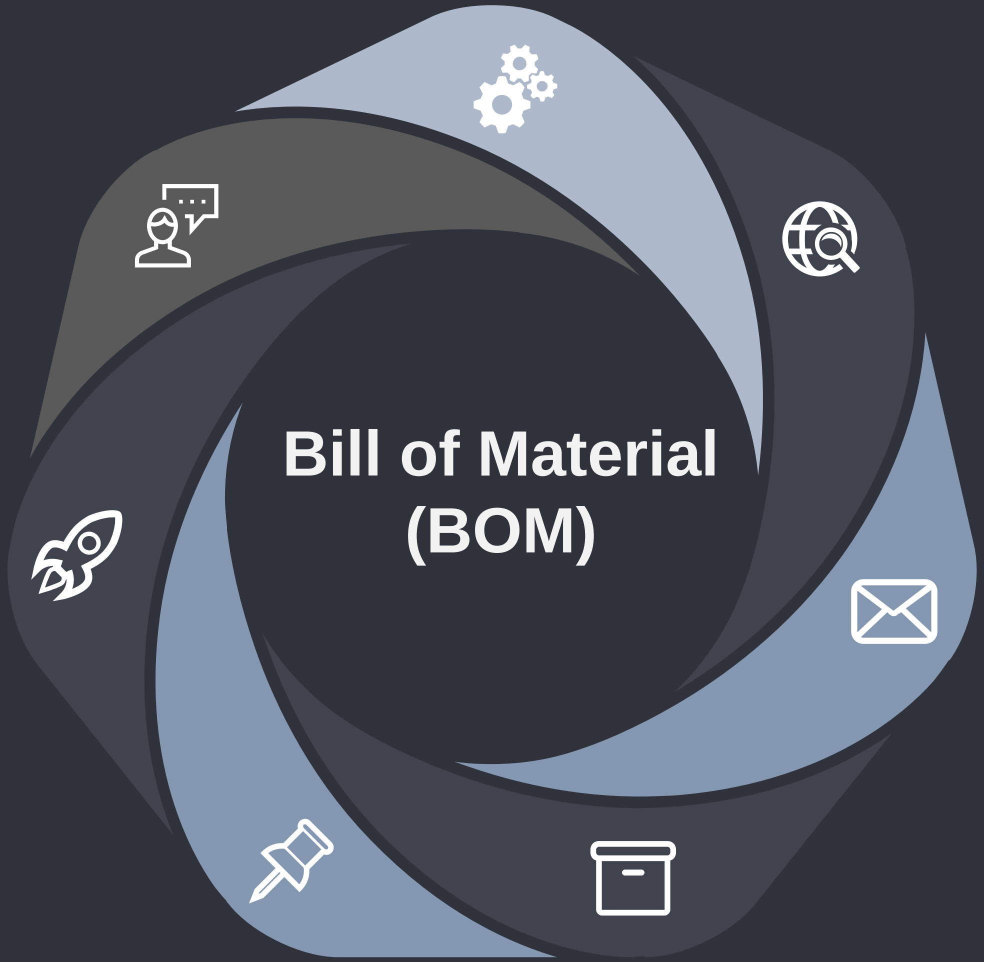


Hence the interaction plot shows the mean sharpness for four different combinations. Among them none is acceptable because of their insignificance (p value is greater than .005). Now as the lines at interaction plot are not parallel, so the plot represents the interaction between two factors.

So from this experiment we can obtain that there is no significance of mild steel and axle on the response

Explanation of Non significant

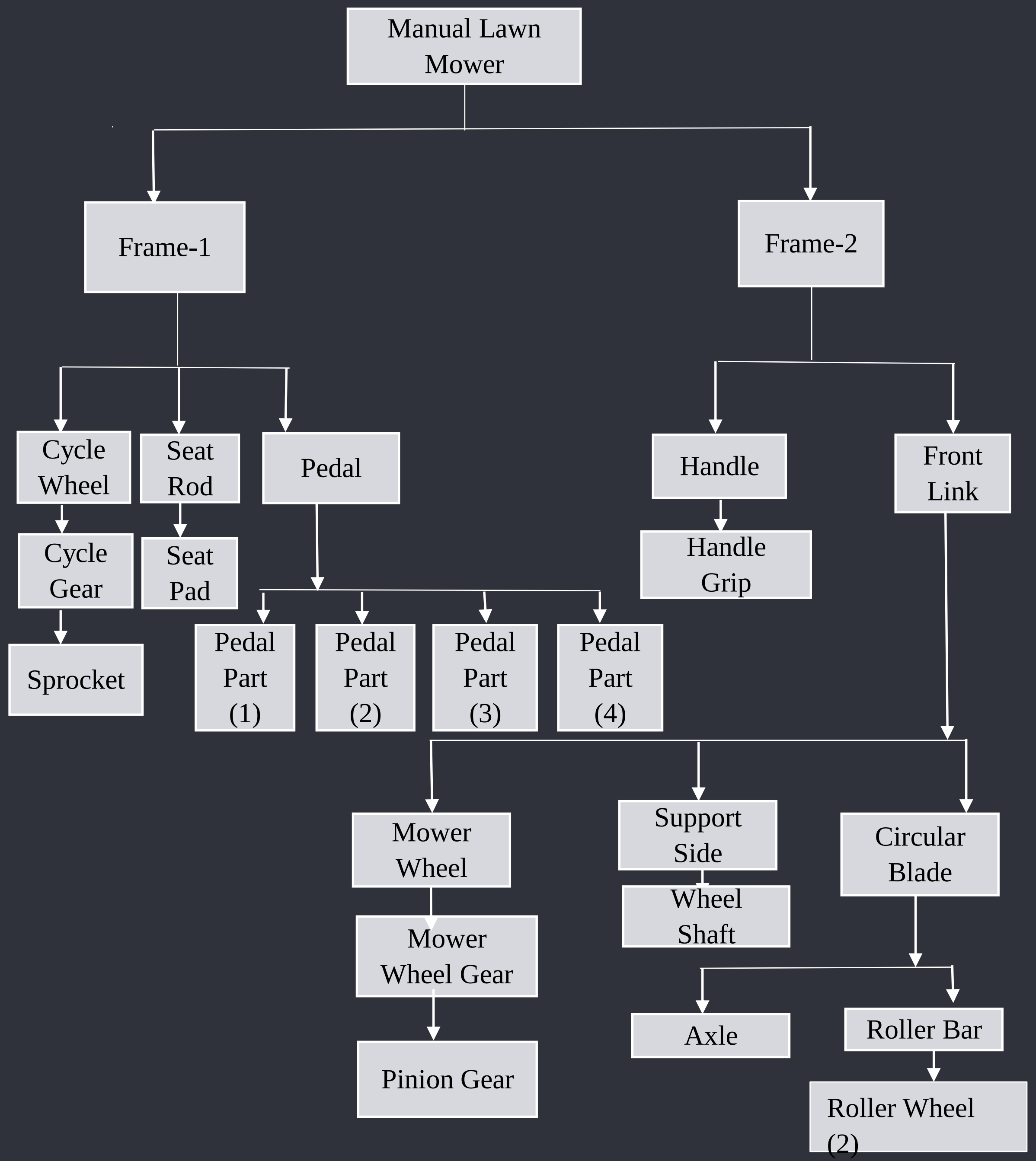
- P value greater than .05
- Represents the non-significance
- Absolutely ok for any kind of statistical approach
- A door-opening for checking other factors and conducting new dataset.


Bill of Material
(BOM)

ITEM NO.	PART NAME	DESCRIPTION	QTY.
1	Frame 1	Cycle's main frame	1
2	Front link	Part which is welded with mower	1
3	Handle	Normal Cycle handle	1
4	Handle grip	Uses to grip the handle	2
5	Seat Rod	Where the Seat pad is joined	1
6	Seat Pad	cycle's seat	1
7	Frame 2	Part which is joined with cycle wheel	1
8	Cycle Wheel		1
9	Cycle Gear	Normal Cycle gear in	1
10	Pedal Part 1		1
11	Pedal Part 2		2

ITEM NO.	PART NAME	DESCRIPTION	QTY.
12	Pedal Part 3		2
13	Pedal Part 4		2
14	Sprocket	Cycle Sprocket	1
15	Mower Wheel		2
16	Pinion Gear	Little gear which transmits rotation to blade from Mower wheel gear	2
17	Mower Wheel Gear	Transmits rotational power to pinion gear from wheel	2
18	Support Side	Where axle, Mower blade, roller bar is set	2
19	Circular blade	Grass cutting blade	1
20	Wheel Shaft		1
21	Roller bar	Where roller wheel is set	1
22	Roller wheel	Give balance to the mower	2

Tree of BOM



Manual Lawn Mower
Frame-1
Frame-2
Cycle Wheel
Seat Rod
Pedal
Handle
Front Link
Cycle Gear
Seat Pad
Handle Grip
Sprocket
Pedal Part (1)
Pedal Part (2)
Pedal Part (3)
Pedal Part (4)
Mower Wheel
Support Side
Circular Blade
Wheel Shaft
Mower Wheel Gear
Axle
Roller Bar
Pinion Gear
Roller Wheel (2)


Lean
Manufacturing
Reduction of Seven
Wastes

Lean Manufacturing

Waste	Cause	Solution
Transportation	• Location of the workshop • Carrying the bicycle to the workshop	• Effective facility location • Lessen the movement of the bicycle
Motion	• Unnecessary movements of materials between blade twisting machine and welding table	• Proper arrangement of blade twisting machine and welding table
Inventory	• More raw materials than needed	• Application of BOM
Over processing	• Design of the cutting blade • Lack of machine • Change in design	• Specialized Blade twisting machine
Defect	• Heavier than expected • Cutting blade not twisted properly • One of the blade is deformed when transported	• Use of composite materials • Specialized Blade twisting machine

Cost Analysis

Prototype Costing

Cost of Raw Materials:

Material	Required Amount	Total Cost (Tk.)
Mild steel sheet	• 4mm - 2 kg • 2mm – 6kg	2500
Mild steel rod	• 2ft • 4ft	1260
Mild steel round bar	• 1inch • 4 inch	990

Total Raw Materials Cost = 4,750 Tk.

Prototype Costing

Labor cost for different manufacturing process:

Process	Total Cost (Tk.)
Sheet Cutting	1500
Welding	2500
Facing	1200
Joining	500
Drilling	1400
Coloring	550

Total labor cost= 7,650 Tk.

Purchasing Cost:

Name of the equipment	Quantity required	Price per unit (BDT)	Cost (Taka)
Cycle	1 piece	6000	6000
Mower wheel	2 pieces	400	800
Roller	2 pieces	100	200
Spray color	2 pieces	200	400
Nut-bolt	10 pieces	30	300

Total Purchasing cost= 7,700 Tk.

Prototype Costing

Manufacturing Cost

Direct material cost

- Raw material cost: 4,750 Tk.
- Purchasing cost: 7,700 Tk.
- Direct material cost: (4,750 + 7,700) = 12,450 Tk.

Direct labor cost

- Labor cost = 7,650 Tk.

Total manufacturing cost: (12,450 + 7,650) = 20,100 Tk.

Cost Analysis for Mass Production

Machine & Associated Cost

Machine	Buying Cost (Tk.)	Qty.	Buying Cost (considering salvage value) Tk.
Arc Welding	249000	1	230500
Grinding Machine	350000	1	264230
Lathe	350000	1	210000
Milling	385150	1	325822
Bending	47000	1	440279
TIG welding	31125	1	31003
Measuring equipment	100000	10	99978
Painting equipment	60000	1	59817

Total machine cost = 19,25,820 Tk.

Cost of Furniture, Computer and Other Accessories

Office Equipment	Buying Cost (considering salvage value) Tk.
Total Furniture and accessories	95056
Computer	143820

Total cost = 2, 38, 876 Tk.

Cost of Raw Materials (Per Unit of Production)

Materials	Cost
AISI-1020 Mild Steel Shaft	510
AISI-1020 Mild Steel Sheet	740
HSS Sheet	1250
Chromalloy Steel	5000

Total cost = 7, 500 Tk./ unit

Labor cost for different manufacturing operation(per month):

Process	Total Cost (Tk.)
Measuring	8000
Welding	18000
Shearing & bending	15000
Grinding	11000
Lathe	21000
Threading & hammering	11000
Assembly & joining	28550
Finishing	6000
coloring	8000

Total labor cost = 1,26,500 Tk./ Per month

Purchasing Cost of Parts

Name of Components	Quantity	Price per unit (Taka)	Cost (Taka)
Cycle Wheel	1	800	800
Mower Wheel	2	650	1300
Brake Set	1	250	250
Bicycle Seat	1	150	150
Teeth Crack Set	1	200	200
Pedal	2	80	160
Sprocket	1	50	50
Sprocket Chain	1	90	90
Roller Wheel	5	200	1000
Total Cost			4000

Total purchasing cost per year = 4000× 2000 = Tk. 80,00000

Manufacturing Cost:

1. Direct Material Cost
Raw Material Cost: **Tk. 1,50,00000**
Purchasing Cost: **Tk. 80, 00,000**
Direct material cost per year:
(**1,50, 00000+ 80,00, 000**) = **Tk.2,30,00000**

2. Direct Labor Cost
Labor Cost per year = **1,518,000**

Total manufacturing overhead per year:
(2, 20, 000 × 12) = TK. 2, 640, 000

Total manufacturing cost per year:
(2, 30, 00, 000+ 1,518,000+2, 640, 000) = Tk.27, 158, 000

3. Manufacturing Overhead Cost per month:

Post	No. of Post	Salary / Person	Total (Tk.)
Production manager	1	40, 000	40, 000
Manufacturing Engineer	1	30, 000	30, 000
Assembly Manager	1	20, 000	20, 000
Design Engineer	1	25, 000	25, 000
Quality control Manager	1	25, 000	25, 000
Factory Rent	NA	NA	30, 000
Power Consumption	NA	NA	20, 000
Supply Chain Engineer	1	20, 000	25,000
Utilities factory	NA	NA	20, 000
Total			2, 20, 000

Administrative cost:

Cost Item / Post	No. of Post	Salary / Person	Total (Tk.)
Chief Executive Manager	1	45, 000	45, 000
HR Manager	1	35, 000	35, 000
Accountant	1	20, 000	20, 000
Secretary	1	12, 000	12, 000
Clerk	2	8, 000	16, 000
Guard (GS4)	3	6, 000	18, 000
Office Rent	NA	NA	30, 000
Power Bill	NA	NA	4,000
Water Bill	NA	NA	2, 000
Total			1, 82, 000

Selling Expense:

Cost Item / Post	No. of Post	Salary / Person	Total (Tk.)
Marketing Executive Manager	1	25, 000	25, 000
Advertisi ng	NA	25, 000	25, 000
Total			50, 000

Total Selling and Administrative expenses per month:
(1, 82, 000 +50,000) = **Tk. 2, 32, 000**
Total Selling and Administrative expenses per year:
(2, 32, 000 × 12) = **Tk. 2, 784, 00**

Break Even Analysis

Fixed cost

Machine cost: **Tk. 19, 25, 820**
Furniture and accessories cost: **Tk. 95, 056**
Building and land cost: TK. **80, 00, 000**
Computer cost: Tk. **1, 43, 820**
Labor cost: Tk. **1,518,000**
Fixed manufacturing overhead cost: **Tk.2, 640, 000**
Fixed selling & administrative cost: **Tk. 2, 784, 000**
Total amount of fixed cost: **Tk. 17, 106, 696 per year**

Variable Cost (for the 2,000 products in the first year)

Raw material cost = **Tk. 1, 50, 00000**
Purchasing cost per year = **Tk. 80, 00000**

Total variable cost per year: (1, 50, 00000 + 80, 00, 000) = **Tk. 23, 000, 000**
Total variable cost per unit production: (**23, 000, 000 / 2000) = Tk. 11,500**
Selling price per unit: **11,500 + 30 % of 11,500** (expecting 30 % profit on sale)
= **Tk. 14,950**

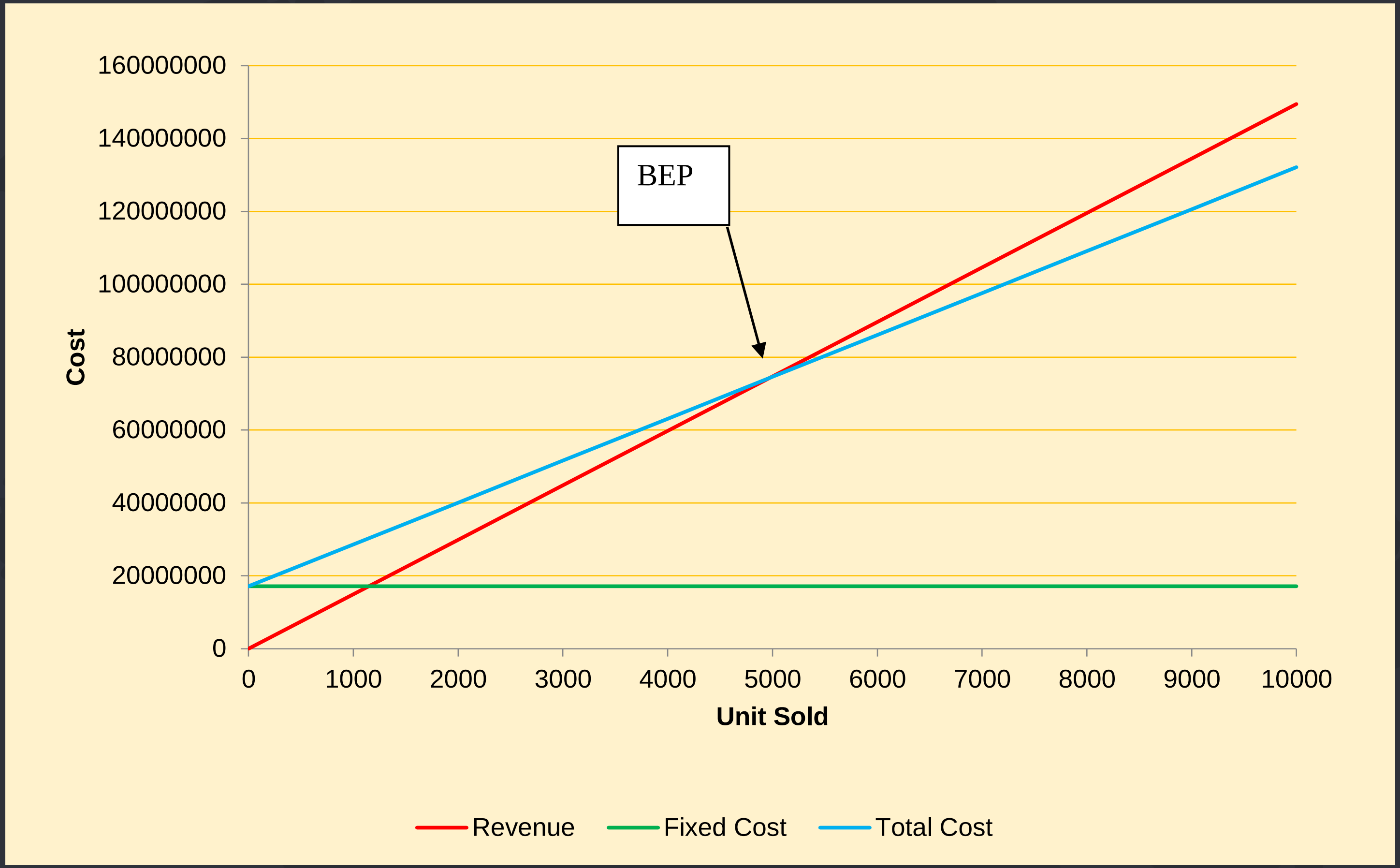
The Equation for Break Even Analysis:

At Beak Even Point,
Selling price × break-even unit (x) = Fixed cost+ Variable cost
Total amount of fixed cost: **Tk. 17, 106, 696**
The total variable cost per unit: **Tk. 11,500**
Selling price per unit: **Tk. 14,375**

So the equation stands as:
14,950x =17, 106, 696 + 11,500x

x ≈ 4958 units

Break even time is 2 years and 5 months



Graphical Representation of Break- Even Analysis

Further Recommendations

- By using composite materials it can be made lightweight to facilitate direction change.
- A tray can be kept underneath to collect waste grasses.
- Appropriate blade sharpening to increase cutting efficiency.

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Thank You

Any Questions?