Appendix H: Cost calculations

Prototyping

- Machined component : raw material cost + R300 / h, in increments of 15 min
- Raw material :
  - Low carbon steel : R25 / kg
  - Brass : R155 / kg
  - Aluminium : R95 / kg
- 3D printing using PLA plastic : R700 / kg + R65 setup cost per part
- For hot rolled carbon steel 1.0 to 3.0 mm sheetmetal parts:

$$Cost\ [R] = 2.2M + 114L \cdot t^{0.2} + 9.6B$$

with M = mass [kg] of plate without internal cut – outs

L = total length [m] of cutting, incl outer perimeter

t = plate thickness [m]

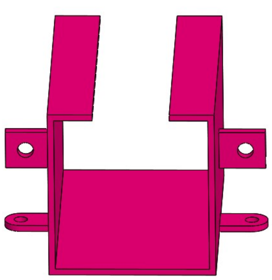
B = number of simple bends

Figure 1: Typical costing inputs

The above costing formulae will be used to calculate cost, the of each part is already determined in **Appendix E.**

3D printed parts

Battery holder

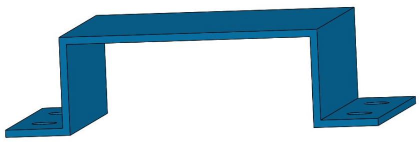


$$m_{bh} := 0.037\ kg$$

$$C_{bh} := \frac{700}{kg} \cdot m_{bh} + 65$$

$$C_{bh} = 90.9$$

Motor lifter

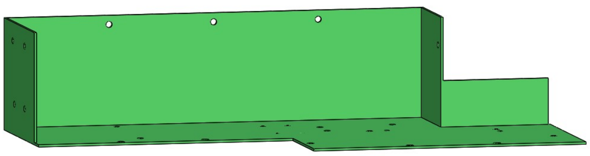


$$m_{ml} := 0.003\ kg$$

$$C_{ml} := \frac{700}{kg} \cdot m_{ml} + 65$$

$$C_{ml} = 67.1$$

Lower housing

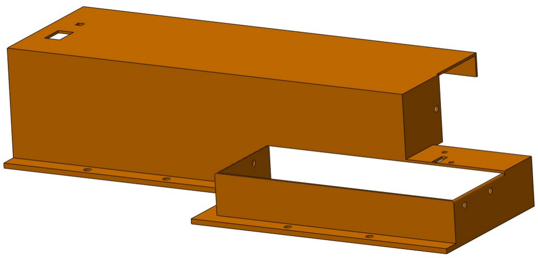


$$m_{lh} := 0.16\ kg$$

$$C_{lh} := \frac{700}{kg} \cdot m_{lh} + 65$$

$$C_{lh} = 177$$

Upper housing

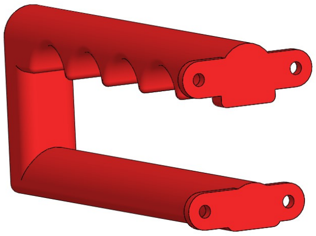


$$m_{uh} := 0.149\ kg$$

$$C_{uh} := \frac{700}{kg} \cdot m_{uh} + 65$$

$$C_{uh} = 169.3$$

Handle



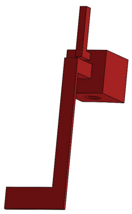
$$m_h := 0.097\ kg$$

$$C_h := \frac{700}{kg} \cdot m_h + 65$$

$$C_h = 132.9$$

Angle lock

$$m_{al} := \left(5.079 \cdot 10^{-4}\right)\ kg$$

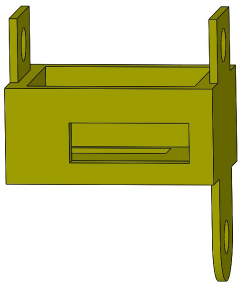


$$C_{al} := \frac{700}{kg} \cdot m_{al} + 65$$

$$C_{al} = 65.356$$

Microswitch holder

$$m_{mch} := 0.004\ kg$$

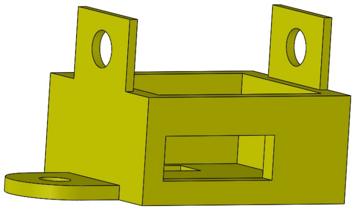


$$C_{mch} := \frac{700}{kg} \cdot m_{mch} + 65$$

$$C_{mch} = 67.8$$

Microswitch holder two

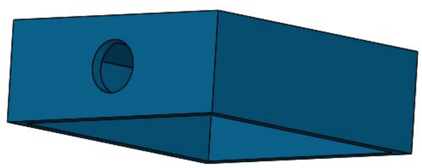
$$m_{mcht} := 0.004\ kg$$



$$C_{mcht} := \frac{700}{kg} \cdot m_{mcht} + 65$$

$$C_{mcht} = 67.8$$

Two microswitch upper holders

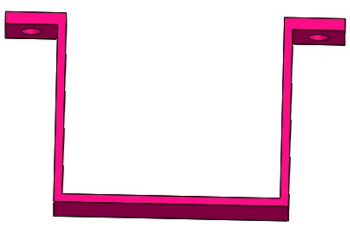


$m_{muh} := 0.004\ kg$

$$C_{muh} := \frac{700}{kg} \cdot m_{muh} + 65$$

$C_{muh} = 67.8$

Two battery clamps



$m_{b\_c} := 0.011\ kg$

$$C_{b\_c} := \frac{700}{kg} \cdot m_{b\_c} + 65$$

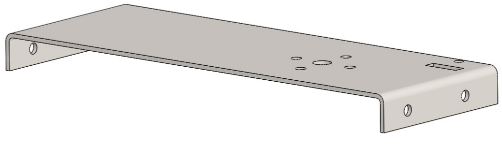
$C_{b\_c} = 72.7$

$$C_{3D\_p} := C_{bh} + C_{ml} + C_{lh} + C_{uh} + C_h + C_{al} + C_{mch} + C_{mcht} + C_{muh} + C_{b\_c}$$

$C_{3D\_p} = 978.656$

Sheet metal parts

Base



$m_{base} := 0.163\ kg$

$L_{base} := 593.79\ mm$

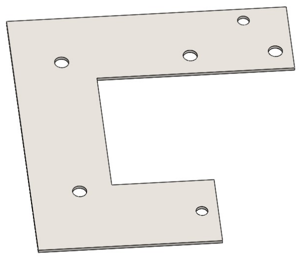
$t_{base} := 1.6\ mm$

$B_{base} := 2$

$$C_{base} := 2.2 \cdot \frac{m_{base}}{kg} + 114 \cdot \frac{L_{base}}{m} \cdot \left(\frac{t_{base}}{1\ m}\right)^{0.2} + 9.6 \cdot B_{base}$$

$C_{base} = 38.238$

Lower shaft support



$$m_{lss} := 0.034\ kg$$

$$L_{lss} := 478.77\ mm$$

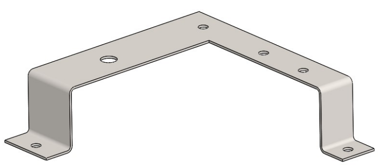
$$t_{lss} := 1\ mm$$

$$B_{lss} := 0$$

$$C_{lss} := 2.2 \cdot \frac{m_{lss}}{kg} + 114 \cdot \frac{L_{lss}}{m} \cdot \left(\frac{t_{lss}}{1\ m}\right)^{0.2} + 9.6 \cdot B_{lss}$$

$$C_{lss} = 13.785$$

Upper shaft support



$$m_{uss} := 0.041\ kg$$

$$L_{uss} := 427.18\ mm$$

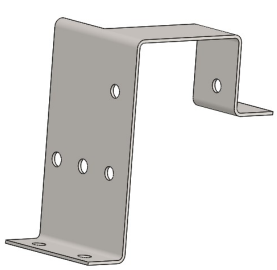
$$t_{uss} := 1\ mm$$

$$B_{uss} := 4$$

$$C_{uss} := 2.2 \cdot \frac{m_{uss}}{kg} + 114 \cdot \frac{L_{uss}}{m} \cdot \left(\frac{t_{uss}}{1\ m}\right)^{0.2} + 9.6 \cdot B_{uss}$$

$$C_{uss} = 50.723$$

Motor support



$$m_{m\_s} := 0.037\ kg$$

$$L_{m\_s} := 615.6\ mm$$

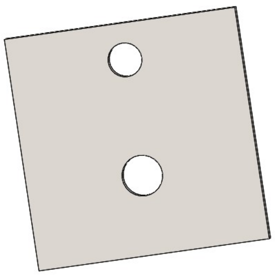
$$t_{m\_s} := 1.6\ mm$$

$$B_{m\_s} := 4$$

$$C_{m\_s} := 2.2 \cdot \frac{m_{m\_s}}{kg} + 114 \cdot \frac{L_{m\_s}}{m} \cdot \left(\frac{t_{m\_s}}{1\ m}\right)^{0.2} + 9.6 \cdot B_{m\_s}$$

$$C_{m\_s} = 57.847$$

Two sheet support



$$m_{sheet\_s} := 0.009\ kg$$

$$L_{sheet\_s} := 120.19\ mm$$

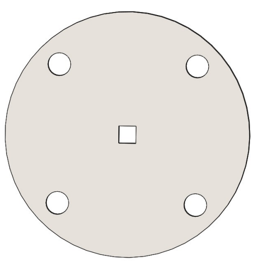
$$t_{sheet\_s} := 1.6\ mm$$

$$B_{sheet\_s} := 0$$

$$C_{sheet\_s} := 2.2 \cdot \frac{m_{sheet\_s}}{kg} + 114 \cdot \frac{L_{sheet\_s}}{m} \cdot \left(\frac{t_{sheet\_s}}{1\ m}\right)^{0.2} + 9.6 \cdot B_{sheet\_s}$$

$$C_{m\_s} = 57.847$$

Two double plate for 48T gear



$$m_{D\_48T} := 0.049\ kg$$

$$L_{D\_48T} := 206.87\ mm$$

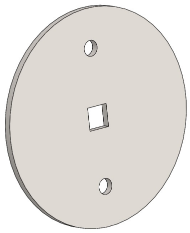
$$t_{D\_48T} := 2\ mm$$

$$B_{D\_48T} := 0$$

$$C_{D\_48T} := 2.2 \cdot \frac{m_{D\_48T}}{kg} + 114 \cdot \frac{L_{D\_48T}}{m} \cdot \left(\frac{t_{D\_48T}}{1\ m}\right)^{0.2} + 9.6 \cdot B_{D\_48T}$$

$$C_{D\_48T} = 6.912$$

Double plate for 36T gear



$m_{D\_36T} := 0.006\ kg$

$L_{D\_36T} := 120.79\ mm$

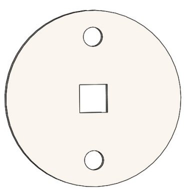
$t_{D\_36T} := 1\ mm$

$B_{D\_36T} := 0$

$$C_{D\_36T} := 2.2 \cdot \frac{m_{D\_36T}}{kg} + 114 \cdot \frac{L_{D\_36T}}{m} \cdot \left(\frac{t_{D\_36T}}{1\ m}\right)^{0.2} + 9.6 \cdot B_{D\_36T}$$

$C_{D\_36T} = 3.472$

Double plate for 24T gear



$m_{D\_24T} := 0.002\ kg$

$L_{D\_24T} := 120.79\ mm$

$t_{D\_24T} := 1\ mm$

$B_{D\_24T} := 0$

$$C_{D\_24T} := 2.2 \cdot \frac{m_{D\_24T}}{kg} + 114 \cdot \frac{L_{D\_24T}}{m} \cdot \left(\frac{t_{D\_24T}}{1\ m}\right)^{0.2} + 9.6 \cdot B_{D\_24T}$$

$C_{D\_24T} = 3.463$

Total cost of the machined parts:

$$C_s := C_{base} + C_{lss} + C_{uss} + C_{m\_s} + C_{sheet\_s} + C_{D\_48T} + C_{D\_36T} + C_{D\_24T}$$

$C_s = 178.241$

Machined parts

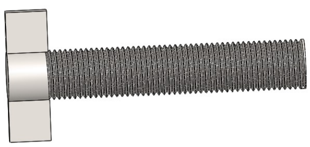
Die positioner

$$m_{Die\_p} := \left(8.888 \cdot 10^{-4}\right)\ kg$$

$$C_{Die\_p} := \frac{25}{kg} \cdot m_{Die\_p} + 300 \cdot \frac{15}{60}$$

$$C_{Die\_p} = 75.022$$

Die lock

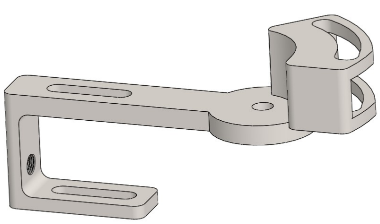


$$m_{Die\_l} := \left(9.615 \cdot 10^{-4}\right)\ kg$$

$$C_{Die\_l} := \frac{25}{kg} \cdot m_{Die\_l} + 300 \cdot \frac{30}{60}$$

$$C_{Die\_l} = 150.024$$

Clamp platform

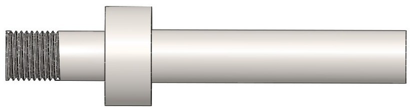


$$m_{Clamp\_p} := 0.024\ kg$$

$$C_{C\_p} := \frac{25}{kg} \cdot m_{Clamp\_p} + 300 \cdot \frac{90}{60}$$

$$C_{C\_p} = 450.6$$

Circular custom shaft

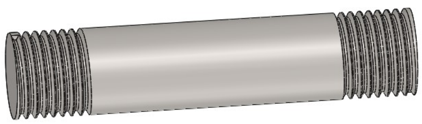


$$m_{Custom\_s} := 0.002\ kg$$

$$C_{C\_s} := \frac{25}{kg} \cdot m_{Custom\_s} + 300 \cdot \frac{30}{60}$$

$$C_{C\_s} = 150.05$$

Angle positioner

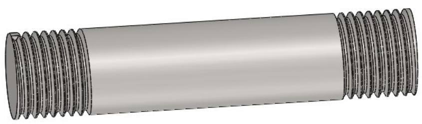


$$m_{Angle\_p} := \left(7.439 \cdot 10^{-4}\right)\ kg$$

$$C_{A\_p} := \frac{25}{kg} \cdot m_{Angle\_p} + 300 \cdot \frac{15}{60}$$

$$C_{A\_p} = 75.019$$

Bending die



$$m_{Die\_b} := 0.002\ kg$$

$$C_{Die\_b} := \frac{25}{kg} \cdot m_{Die\_b} + 300 \cdot \frac{15}{60}$$

$$C_{Die\_b} = 75.05$$

Total cost of the machined parts:

$$C_{machine} := C_{Die\_p} + C_{Die\_l} + C_{C\_p} + C_{C\_s} + C_{A\_p} + C_{Die\_b}$$

$$C_{machine} = 975.765$$

Bought parts

Some parts will be bought. Their mass is given.

100rpm Motor: $C_{motor} := 315$

Two 12T spur gears: $C_{12T\_s} := 2 \cdot 4.5 = 9$

Two 24T bevel gears: $C_{24T\_b} := 2 \cdot 6 = 12$

Two 36T spur gears: $C_{36T\_s} := 2 \cdot 18 = 36$

Two 48T spur gears: $C_{48T\_s} := 2 \cdot 9 = 18$

Square shaft 30 long: $C_{30\_sq} := 160 \cdot \frac{30}{1000} = 4.8$

Square shaft 70 long: $C_{70\_sq} := 160 \cdot \frac{70}{1000} = 11.2$

Square shaft 45 long: $C_{45\_sq} := 160 \cdot \frac{45}{1000} = 7.2$

Three high strength
square shaft 30 long: $C_{30\_hsq} := 3 \cdot 160 \cdot \frac{30}{1000} = 14.4$

Shaft coupler: $C_{shaft\_c} := 25.5$

Four cells with caps: $C_{cell\_w\_caps} := 4 \cdot 54 = 216$

Two cell links: $C_{cell\_link} := 2 \cdot 1 = 2$

Fused link: $C_{fused\_link} := 25$

Two microswitches: $C_{microswitch} := 2 \cdot 17 = 34$

Ten spacers 3.2 long: $C_{3.2\_spacer} := 10 \cdot 3 = 30$

Spacer 6.4 long: $C_{6.4\_spacer} := 3$

Three spacers 9.5 long: $C_{9.5\_spacer} := 3 \cdot 3 = 9$

Two spacers 12.7 long: $C_{12.7\_spacer} := 2 \cdot 3 = 6$

Two button head screws: $C_{b\_screws} := 2 \cdot 3.5 = 7$

Six (2.9x6.5) self tapping screws: $C_{2.9x6.5\_screws} := 6 \cdot 1 = 6$

Twelve (3.5x9.5) self tapping screws: $C_{3.5x9.5\_screws} := 12 \cdot 1 = 12$

Four (4.2x16) self tapping screws: $C_{4.2x16\_screws} := 12 \cdot 1 = 12$

Twenty one (4.2x9.5) self tapping screws: $C_{4.2x9.5\_screws} := 21 \cdot 1 = 21$

Seven hex M5 (16x10) bolts: $C_{16x10\_bolt} := 7 \cdot 2 = 14$

Seven hex M5 nut: $C_{M5\_nut} := 7 \cdot 2 = 14$

Five hex M3 nut: $C_{M3\_nut} := 5 \cdot 2 = 10$

Six M5 washers: $C_{M5\_washer} := 6 \cdot 1 = 6$

Big roller: $C_{Big\_roller} := 65 = 65$

Push button: $C_{push\_b} := 75$

Control switch: $C_{control\_s} := 65$

$$C_1 := C_{control\_s} + C_{push\_b} + C_{Big\_roller} + C_{M5\_washer} + C_{M5\_nut} + C_{M3\_nut} + C_{16x10\_bolt} + C_{4.2x9.5\_screws}$$

$$C_2 := C_{4.2x16\_screws} + C_{3.5x9.5\_screws} + C_{2.9x6.5\_screws} + C_{b\_screws} + C_{12.7\_spacer} + C_{9.5\_spacer} + C_{6.4\_spacer}$$

$$C_3 := C_{3.2\_spacer} + C_{microswitch} + C_{fused\_link} + C_{cell\_link} + C_{cell\_w\_caps} + C_{shaft\_c} + C_{30\_hsq} + C_{45\_sq}$$

$$C_4 := C_{70\_sq} + C_{30\_sq} + C_{48T\_s} + C_{36T\_s} + C_{24T\_b} + C_{12T\_s} + C_{motor}$$

Total cost of the bought parts in rands:

$$C_{bought} := C_1 + C_2 + C_3 + C_4$$

$$C_{bought} = 694.1$$

Labour cost

The labour cost needs to be taken into account. The design needs to be assembled properly. An artisan will be perfect for this because they are skilled in manual labour fields such as:

water technology (plumbing)
engineering (electrical/mechanical/automotive etc)
fashion
building technology

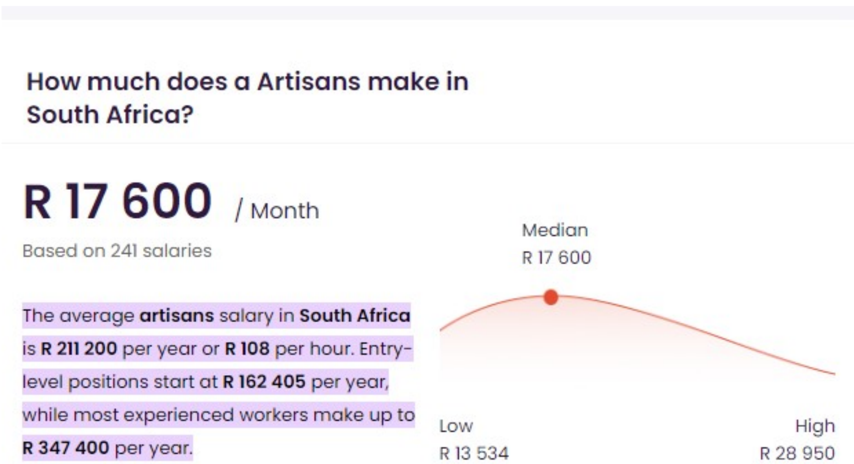


Figure 1: average artisan salary

The above figure is from talent.com

Number of artisan needed: $N_{artisan} := 1$

Artisan cost: $C_{artisan} := \frac{108}{hr}$

Number of hours that an artisan will work: $N_{hours} := 1.5\ hr$

Labour cost: $C_{labour} := N_{artisan} \cdot C_{artisan} \cdot N_{hours}$

$C_{labour} = 162$

The prototype cost in rands: $C_{tot} := C_{bought} + C_{machine} + C_s + C_{3D\_p} + C_{labour}$

$$C_{tot} = 2.989 \cdot 10^3$$

Development costs

Development costs are commonly referred to as research and development costs. These costs can include a host of expenses, such as marketing analysis, developmental engineering and customer surveying.

Activities that are typically considered as research and development include:

Research to bring about new knowledge
Creation of product and process designs
Testing processes and products
Modifying processes and products
Designing prototypes
Testing prototypes
Designing new tools

Certain number of engineers need to be assigned to perform the above mentioned activities.

The cost per engineer needs to be stated and also how long it will take to complete research and development

Number of engineers that will be assigned for R&D: $N_{engineer} := 2$

The cost of one engineer: $C_{engineer} := \frac{200}{hr}$

Number of days dedicated for R&D per month:

$N_{days} := 20$

Number of hours dedicated for R&D day:

$N_{hours} := 8\ hr$

Number of months it will take for research and development:

$N_{dev\_months} := 2$

Number of demonstrations needed:

$N_{demo} := 4$

Prototype cost:

$C_{prototype} := C_{tot}$

$C_{prototype} = 2.989 \cdot 10^{3}$

Using the above information, the development cost can be determined.

Development cost:

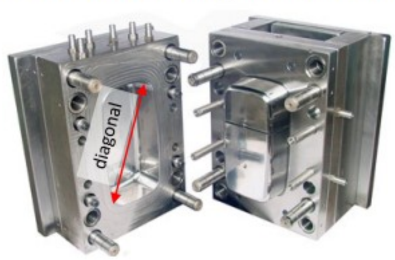
$$C_{development} := N_{demo} \cdot C_{prototype} + N_{engineer} \cdot C_{engineer} \cdot N_{days} \cdot N_{hours} \cdot N_{dev\_months}$$

$$C_{development} = 1.4 \cdot 10^{5}$$

Ramp-up costs

Mass production

- CNC machined component : Raw material cost x fabrication factor (1.5 to 3 depending upon complexity)
- Injection moulded ABS plastic : R20 / kg x 2 for machine time
- Single cavity simple injection mould :
    - R25 000 + R250 / mm x diagonal size (max 150mm)
    - R35 000 + R250 / mm x diagonal size (max 250mm)
    - R42 000 + R250 / mm x diagonal size (max 350mm)



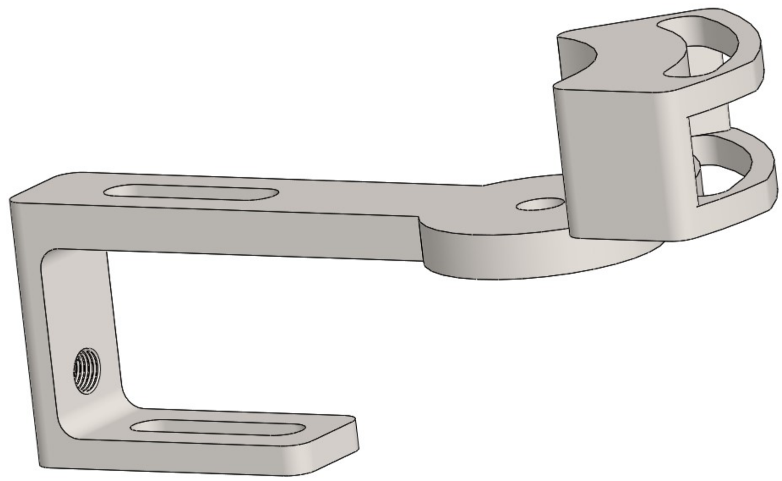
- Stamped sheet metal parts : Un-bent raw material cost x 1.5 for machine time
- Steel stamping tool: Use costing method of injection tool, but increased by factor 1.5.

Figure 1: Mass production

The above figure will be used to determine the cost of tooling.

Complex parts will be made using single cavity simple injection mould

Clamp platform



Calculated mass: $m_{Clamp\_p} = 0.024\ kg$

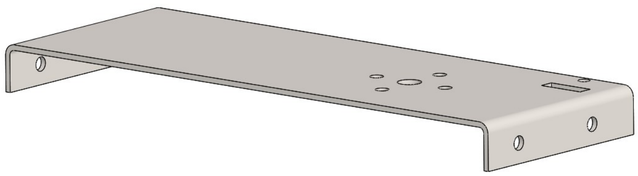
Diagonal size: $D_{Clamp\_p} := 96.52\ mm$

Tooling cost in rands: $T_{Clamp\_p} := 25000 + \frac{250}{mm} \cdot D_{Clamp\_p}$

$$T_{Clamp\_p} = 4.913 \cdot 10^4$$

Stamped sheet metal parts needs steel stamping tool to create the desired shape

Base



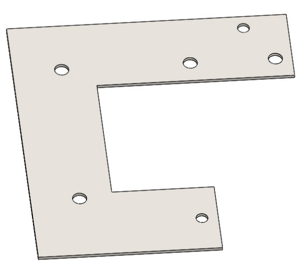
Calculated mass: $m_{base} = 0.163\ kg$

Diagonal size: $D_{base} := 189.2\ mm$

Tooling cost in rands: $T_{base} := 35000 + \frac{250}{mm} \cdot D_{base}$

$T_{base} = 8.23 \cdot 10^{4}$

Lower shaft support



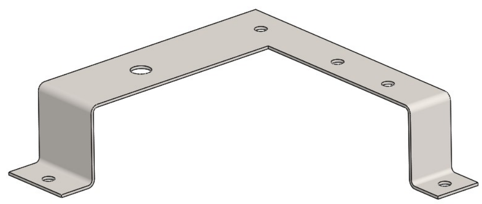
Calculated mass: $m_{lss} = 0.034\ kg$

Diagonal size: $D_{lss} := 121\ mm$

Tooling cost in rands: $T_{lss} := 25000 + \frac{250}{mm} \cdot D_{lss}$

$T_{lss} = 5.525 \cdot 10^{4}$

Upper shaft support



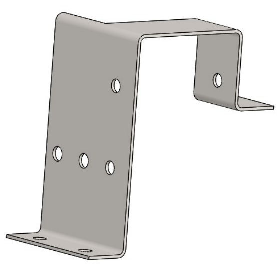
Calculated mass: $m_{uss} = 0.041\ kg$

Diagonal size: $D_{uss} := 142\ mm$

Tooling cost in rands: $T_{uss} := 25000 + \frac{250}{mm} \cdot D_{uss}$

$T_{uss} = 6.05 \cdot 10^4$

Motor support



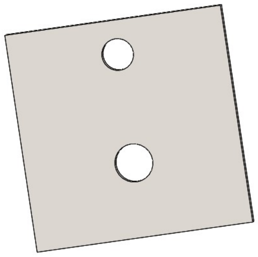
Calculated mass: $m_{m\_s} = 0.037\ kg$

Diagonal size: $D_{m\_s} := 75.47\ mm$

Tooling cost in rands: $T_{m\_s} := 25000 + \frac{250}{mm} \cdot D_{m\_s}$

$T_{m\_s} = 4.387 \cdot 10^4$

Two sheet support



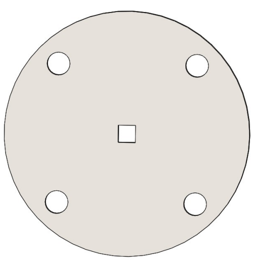
Calculated mass: $m_{sheet\_s} = 0.009\ kg$

Diagonal size: $D_{sheet\_s} := 33.94\ mm$

Tooling cost in rands: $T_{sheet\_s} := 25000 + \frac{250}{mm} \cdot D_{sheet\_s}$

$T_{sheet\_s} = 3.349 \cdot 10^{4}$

Two double plate for 48T gear



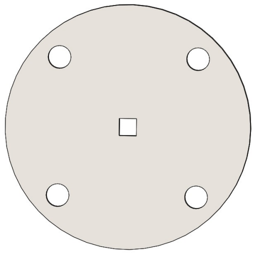
Calculated mass: $m_{D\_48T} = 0.049\ kg$

Diagonal size: $D_{D\_48T} := 48\ mm$

Tooling cost in rands: $T_{D\_48T} := 25000 + \frac{250}{mm} \cdot D_{D\_48T}$

$T_{D\_48T} = 3.7 \cdot 10^{4}$

Double plate for 36T gear



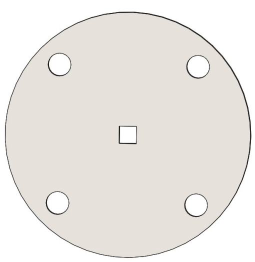
Calculated mass: $m_{D\_36T} = 0.006\ kg$

Diagonal size: $D_{D\_36T} := 30\ mm$

Tooling cost in rands: $T_{D\_36T} := 25000 + \frac{250}{mm} \cdot D_{D\_36T}$

$T_{D\_36T} = 3.25 \cdot 10^4$

<u>Double plate for 24T gear</u>



Calculated mass: $m_{D\_24T} = 0.002\ kg$

Diagonal size: $D_{D\_24T} := 20\ mm$

Tooling cost in rands: $T_{D\_24T} := 25000 + \frac{250}{mm} \cdot D_{D\_24T}$

$T_{D\_24T} = 3 \cdot 10^4$

Total tooling cost in rands:

$$T_{tot} := T_{D\_24T} + T_{D\_36T} + T_{D\_48T} + T_{sheet\_s} + T_{m\_s} + T_{uss} + T_{lss} + T_{base} + T_{Clamp\_p}$$

$$T_{tot} = 4.24 \cdot 10^5$$

The following prototypes will be made:

The number of the alpha prototypes: $N_{alpha} := 3$

The cost of each alpha prototype: $C_{alpha} := C_{tot}$

$$C_{alpha} = 2.989 \cdot 10^3$$

The number of the beta prototypes: $N_{beta} := 6$

The cost of each alpha prototype: $C_{beta} := C_{tot} \cdot 0.75$

$$C_{beta} = 2.242 \cdot 10^3$$

Total ramp-up cost: $C_{ramp\_up} := T_{tot} + N_{alpha} \cdot C_{alpha} + N_{beta} \cdot C_{beta}$

$$C_{ramp\_up} = 4.464 \cdot 10^5$$

Volume production cost

Mass production

- CNC machined component : Raw material cost x fabrication factor (1.5 to 3 depending upon complexity)
- Injection moulded ABS plastic : R20 / kg x 2 for machine time
- Single cavity simple injection mould :
  - R25 000 + R250 / mm x diagonal size (max 150mm)
  - R35 000 + R250 / mm x diagonal size (max 250mm)
  - R42 000 + R250 / mm x diagonal size (max 350mm)

- Stamped sheet metal parts : Un-bent raw material cost x 1.5 for machine time
- Steel stamping tool: Use costing method of injection tool, but increased by factor 1.5.

Figure 1: Mass production

The above figure will be used to determine the cost of the volume production cost

The following parts will be made with injection moulded ABS plastic

<u>Battery holder</u>

Calculated mass: $m_{bh} = 0.037\ kg$

Production cost in rands: $P_{bh} := \frac{20}{kg} \cdot m_{bh} \cdot 2$

$P_{bh} = 1.48$

<u>Motor lifter</u>

Calculated mass: $m_{ml} = 0.003\ kg$

Production cost in rands: $P_{ml} := \frac{20}{kg} \cdot m_{ml} \cdot 2$

$P_{ml} = 0.12$

Lower housing

Calculated mass: $m_{lh}=0.16\ kg$

Production cost in rands: $P_{lh}:=\frac{20}{kg}\cdot m_{lh}\cdot 2$

$P_{lh}=6.4$

Upper housing

Calculated mass: $m_{uh}=0.149\ kg$

Production cost in rands: $P_{uh}:=\frac{20}{kg}\cdot m_{uh}\cdot 2$

$P_{uh}=5.96$

Handle

Calculated mass: $m_{h}=0.097\ kg$

Production cost in rands: $P_{h}:=\frac{20}{kg}\cdot m_{h}\cdot 2$

$P_{h}=3.88$

Angle lock

Calculated mass: $m_{al}=\left(5.079\cdot 10^{-4}\right)\ kg$

Production cost in rands: $P_{al}:=\frac{20}{kg}\cdot m_{al}\cdot 2$

$P_{al}=0.02$

Microswitch holder

Calculated mass: $m_{msh}=0.004\ kg$

Production cost in rands:

$$P_{mch} := \frac{20}{kg} \cdot m_{mch} \cdot 2$$

$$P_{mch} = 0.16$$

Microswitch holder two

Calculated mass:

$$m_{mcht} = 0.004\ kg$$

Production cost in rands:

$$P_{mcht} := \frac{20}{kg} \cdot m_{mcht} \cdot 2$$

$$P_{mcht} = 0.16$$

Two microswitch upper holders

Calculated mass:

$$m_{muh} = 0.004\ kg$$

Production cost in rands:

$$P_{muh} := 2 \cdot \frac{20}{kg} \cdot m_{mcht} \cdot 2$$

$$P_{muh} = 0.32$$

Two battery clamps

Calculated mass:

$$m_{b\_c} = 0.011\ kg$$

Production cost in rands:

$$P_{b\_c} := 2 \cdot \frac{20}{kg} \cdot m_{b\_c} \cdot 2$$

$$P_{b\_c} = 0.88$$

Total cost of injection
moulded parts in rands:

.

$$P_{injection} := P_{bh} + P_{ml} + P_{lh} + P_{uh} + P_{h} + P_{al} + P_{mch} + P_{mcht} + P_{muh} + P_{b\_c}$$

$$P_{injection} = 19.38$$

The following parts will be made by stamped sheet metal

<u>Base</u>

Calculated mass: $m_{base} = 0.163\ kg$

Production cost in rands: $P_{base} := \frac{25}{kg} \cdot m_{base} \cdot 1.5$

$P_{base} = 6.113$

<u>Lower shaft support</u>

Calculated mass: $m_{lss} = 0.034\ kg$

Production cost in rands: $P_{lss} := \frac{25}{kg} \cdot m_{lss} \cdot 1.5$

$P_{lss} = 1.275$

<u>Upper shaft support</u>

Calculated mass: $m_{uss} = 0.041\ kg$

Production cost in rands: $P_{uss} := \frac{25}{kg} \cdot m_{uss} \cdot 1.5$

$P_{uss} = 1.538$

Motor support

Calculated mass: $m_{m\_s} = 0.037\ kg$

Production cost in rands: $P_{m\_s} := \frac{25}{kg} \cdot m_{m\_s} \cdot 1.5$

$P_{m\_s} = 1.388$

Two sheet support

Calculated mass: $m_{sheet\_s} = 0.009\ kg$

Production cost in rands: $P_{sheet\_s} := 2 \cdot \frac{25}{kg} \cdot m_{sheet\_s} \cdot 1.5$

$P_{sheet\_s} = 0.675$

Two double plate for 48T gear

Calculated mass: $m_{D\_48T} = 0.049\ kg$

Production cost in rands: $P_{D\_48T} := 2 \cdot \frac{25}{kg} \cdot m_{D\_48T} \cdot 1.5$

$P_{D\_48T} = 3.675$

Double plate for 36T gear

Calculated mass: $m_{D\_36T} = 0.006\ kg$

Production cost in rands: $P_{D\_36T} := \frac{25}{kg} \cdot m_{D\_36T} \cdot 1.5$

$P_{D\_36T} = 0.225$

Double plate for 24T gear

Calculated mass: $m_{D\_24T} = 0.002\ kg$

Production cost in rands: $P_{D\_24T} := \frac{25}{kg} \cdot m_{D\_24T} \cdot 1.5$

$P_{D\_24T} = 0.075$

Total production cost of the stamped sheet metal parts in rands:

$$P_{sheet} := P_{base} + P_{lss} + P_{uss} + P_{m\_s} + P_{sheet\_s} + P_{D\_48T} + P_{D\_36T} + P_{D\_24T}$$

$$P_{sheet} = 14.963$$

The following parts will be made with a CNC machine.

Die positioner

Calculated mass: $m_{Die\_p} = \left(8.888 \cdot 10^{-4}\right)\ kg$

Production cost in rands: $P_{Die\_p} := \frac{25}{kg} \cdot m_{Die\_p} \cdot 1.5$

$P_{Die\_p} = 0.033$

Die lock

Calculated mass: $m_{Die\_l} = \left(9.615 \cdot 10^{-4}\right)\ kg$

Production cost in rands: $P_{Die\_l} := \frac{25}{kg} \cdot m_{Die\_l} \cdot 1.9$

$$P_{Die\_l} = 0.046$$

Clamp platform

Calculated mass: $m_{Clamp\_p} = 0.024\ kg$

Production cost in rands: $P_{Clamp\_p} := \frac{25}{kg} \cdot m_{Clamp\_p} \cdot 3$

$$P_{Clamp\_p} = 1.8$$

Circular custom shaft

Calculated mass: $m_{Custom\_s} = 0.002\ kg$

Production cost in rands: $P_{Custom\_s} := \frac{25}{kg} \cdot m_{Custom\_s} \cdot 2.1$

$$P_{Custom\_s} = 0.105$$

Angle positioner

Calculated mass: $m_{Angle\_p} = \left(7.439 \cdot 10^{-4}\right)\ kg$

Production cost in rands: $P_{Angle\_p} := \frac{25}{kg} \cdot m_{Angle\_p} \cdot 1.5$

$$P_{Angle\_p} = 0.028$$

Bending die

Calculated mass: $m_{Die\_b} = 0.002\ kg$

Production cost in rands: $P_{Die\_b} := \frac{25}{kg} \cdot m_{Die\_b} \cdot 1.5$

$$P_{Die\_b} = 0.075$$

Total production cost of the
CNC machined parts:

$$P_{CNC} := P_{Die\_p} + P_{Die\_l} + P_{Clamp\_p} + P_{Custom\_s} + P_{Angle\_p} + P_{Die\_b}$$

$$P_{CNC} = 2.087$$

The cost of parts that will be bought "off the shelf" will remain the same.

Total production cost of the
"off the shelf" parts:

$$P_{bought} := C_{bought}$$

$$P_{bought} = 694.1$$

The labour cost will remain the same.

Total production cost due to
labour in rands:

$$P_{labour} := C_{labour}$$

$$P_{labour} = 162$$

Now the volume production cost per product can be determined by adding all the production costs.

Volume production per
product in rands:

$$P_{volume} := P_{bought} + P_{CNC} + P_{sheet} + P_{injection} + P_{labour}$$

$$P_{volume} = 892.53$$