|  |  |  |  |
| --- | --- | --- | --- |
| **Appendix I: Life Cycle Analysis** | 60 |  |  |
| Are the system boundaries explained appropriately? | 20 | generally complete with minor error or omission | substantial with no errors and all relevant costs considered. |
| Are Lifetime Operating and Maintenance Costs appropriately detailed? | 20 | generally complete with minor error or omission | substantial with no errors and all relevant costs considered. |
| Are End of Life and Disposal considerations detailed? | 20 | generally complete with minor error or omission | substantial with no errors and all relevant costs considered. |

Our Life cycle analysis is defined within some boundaries. We decided to focus on the environmental impact (specifically global warming potential) in material extraction and manufacturing of our device’s three key parts: the drivetrain, the three wheels for stability, and the frame that connects them all together. Together, these parts make up approximately over 80% of the total mass of our design, making the analysis a good approximation for the full product. This percentage approximation was derived from inspection and estimation of our design model and the GRIT Freedom chair specifications, which our design geometry is similar to. The full device and its parts were analyzed for material excavation and manufacture GWP, lifetime operation and maintenance cost, and end of life disposal.

**Material Extraction**

The analysis for material extraction includes references from our off-the-shelf parts list in Appendix G, and the known geometry of existing GRIT chair. For the frame, the GRIT chair was used for approximation since the material and geometry are similar. The ratchet mechanism is accounted for in the freehub of the wheels. The parts considered were mostly made of aluminum, steel, or rubber, so these are the materials we focus on. The table below shows the equivalent kg of C02 emissions for each material extracted, and the total for the full product. Therefore, our TrailRider’s GWP for material extraction is 34.8 kg of C02.

*Table X.Y*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Part \ Material** | **Aluminum (kg)** | **Stainless Steel (kg)** | **Rubber (kg)** | **Total Part Weight (kg)** |
| Frame | 0 | 15 | 0 | 15 |
| Wheels (x2) | 0.122 | 1.6 | 1.34 | 3.062 |
| Chains (x2) | 0 | 0.5 | 0 | 0.5 |
| Sprocket set (x2) | 0 | 1.464 | 0 | 1.464 |
| Levers (x2) | 0 | 1.12 | 0 | 1.12 |
| Total Material Weight (kg) | 0.122 | 19.684 | 1.34 | **21.146** |
| CO2 conversion (kg/kg) | 8.14 | 1.77 | 3.18 | - |
| Total CO2 (kg) | **0.99308** | **34.84068** | **4.2612** | **40.09496** |

Reference

* [https://www.winnipeg.ca/finance/findata/matmgt/documents/2012/682-2012/682-2012\_Appendix\_H-WSTP\_South\_End\_Plant\_Process\_Selection\_Report/Appendix%207.pd](https://www.winnipeg.ca/finance/findata/matmgt/documents/2012/682-2012/682-2012_Appendix_H-WSTP_South_End_Plant_Process_Selection_Report/Appendix%207.pdf)
* <https://weightweenies.starbike.com/listings.php>

**Manufacturing**

The analysis for manufacturing is estimated only from 1.5x manufacturing of a bike frame, two wheels and the chains due to lack of time and resources. We multiply this approximation by 1.5 to account for the manufacture of a more complete product, noting that our TrailRider has two sets of drivetrain and a bigger frame compared to a bike. From research, it takes 110 kg of CO2 to manufacture for every kg of frame, two wheels, and chains combined. We can approximate the GWP for manufacturing a full chair by multiplying 110 kg CO2 with our total weight 21.15 kg and the factor 1.5. This results in a total of 3489.75 kg of CO2 emissions. Note that this is a very rough approximation, but helpful to see the order of magnitude.

|  |  |  |
| --- | --- | --- |
| **Part** | **CO2 per kg** | **Total CO2 (kg) x1.5** |
| Frame | 63.4 | 1426.5 |
| Wheels | 10.8 | 49.6044 |
| Chains | 7.66 | 5.745 |
| Total | - | **1481.8494** |

Reference

* <https://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/8483/Duke_MP_Published.pdf>

**Operation and Maintenance Cost**

Operation and maintenance will only account for lubrication of the chains. We omit replacing any parts because the four hours a week (two 2-hour rides on weekends) of operation for 10 years in an unpaved bike trail have been taken into account in our engineering calculations and is sufficient for no failure. Our maintenance costs will consider lubricating the chains, chain inspection and potential replacement, and inflating the wheels.

Chains are expected to be one of the parts requiring the most maintenance. It is said to be best practice to clean and lubricate the chains about once a month. Each chain needs 20 mL of lubrication. For 10 years of operation, this comes down to 120 months. In total we would need 4800mL of chain lube. Chain lube costs about $13 for 120 mL. This means 10 years of chain lubrication will cost a total $520. For safety and efficiency, it is required to inspect the chains every three months for any wear and in need of replacement. Inspection can be done at home at no cost. As a conservative approach, replacing chains may be estimated once a year. Chain replacing service costs about $15, and the chains itself are together $48.12. This totals to $63.12 each year. So, this totals to $631.20 for chain replacement for 10 years.

Another maintenance to consider is inflating the tires. This is fairly simple, and can be done by the owner. A one time cost of $42 for a bike pump, since our chair’s wheels are simply mountain bike wheels.

|  |  |
| --- | --- |
| **Maintenance (10 years)** | **Cost** |
| Chain Lubrication | $520 |
| Chain Replacement | $631.20 |
| Tire Inflation | $42 |
| Total Maintenance Cost | $1,193.20 |

References

* <https://www.mec.ca/en/product/5063-555/Wet-Chain-Lube-120ml> (chain lube price)
* <http://www.bikesforall.ca/bike-service/> (chain replace service)
* <https://www.mec.ca/en/product/5060-607/Apex-Floor-Pump?colour=ANC00&gclid=CjwKCAiA8K7uBRBBEiwACOm4d973JtYIRICeAfcIse0ci8SxgUsz2Vc5o2agHFohtC-ItSTiTOEzeBoCKcsQAvD_BwE> (bike pump)

**End of Life**

Because OurTrailRider is mostly made of steel and aluminum, we can scrap these and reuse them for other applications. The most concerning parts in our scope are the rubber tires. Tires are known to fill up landfill space. There are efforts to reusing them into new tires, but only 5% of the weight can be integrated into a new tire, but this new tire is also weaker and less efficient. For the rest of the TrailRider, it is possible to bring this into a transfer station where they will sort out the metals and the tires and other recyclable materials.

<https://en.wikipedia.org/wiki/Tire_recycling>