**Sherpas Required - 40%**

The number of Sherpas required to use the device is based on an average round trip on our predefined terrain (Prospect Point, Stanley Park and Pacific Spirit Park). Note that this criterion does not take into account the specific power output of each Sherpa; it assumes an ‘average’ healthy individual such as the BCMOS volunteers.

The scale is based on our estimate of customer satisfaction with each number of required Sherpas.

|  |  |
| --- | --- |
| **Score** | **Description** |
| 10 | Rider can use the device completely independently on a round trip on a flat trail |
| 9 |  |
| 8 |  |
| 7 | A round trip can be completed with one Sherpa |
| 6 |  |
| 5 |  |
| 4 |  |
| 3 | A round trip can be completed with two Sherpas |
| 2 |  |
| 1 | Device requires more than two Sherpas |

**Mechanical Efficiency from Rider - 35%**

Mechanical efficiency is defined as the percentage of the power outputted by the rider to the resulting power outputted by the device. Based on [this article](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1332474/pdf/brjsmed00001-0049.pdf), the mechanical efficiency of an arm-crank ergometer is ~20%, whereas for a conventional wheelchair drive it is ~10%.

The satisfaction scale is based on the calculation shown in the Appendix, with a 10 being the required mechanical efficiency that would allow the rider to independently overcome rolling resistance for a one hour trip on flat ground.

|  |  |
| --- | --- |
| **Score** | **Description** |
| 10 | Mechanical efficiency of >17% |
| 9 | Mechanical efficiency of 13% |
| 8 | 10% |
| 7 | 8% |
| 6 | 6% |
| 5 | 5% |
| 4 | 4% |
| 3 | 3% |
| 2 | 2% |
| 1 | 1% |

**Cost - 25%**

Production cost is quantified by a rough estimate using our team’s knowledge and research of the mechanical components in each concept. The cost inherently includes the simplicity criterion.

The scale was developed to reflect customer satisfaction at each price point; the maximum allowable cost is defined as $9000 because that is the average disposable income for individuals with disabilities ([Exhibit 1](https://www.rod-group.com/sites/default/files/2016%20Annual%20Report%20-%20The%20Global%20Economics%20of%20Disability.pdf), page 11).

|  |  |
| --- | --- |
| **Score** | **Description** |
| 10 | The device costs ≤ $3000 CAD |
| 9 | $3001 - $3500 CAD → [GRIT Freedom Chair](https://www.gogrit.us/) |
| 8 | $3501 - $4000 CAD |
| 7 | $ 4000 - 4500 CAD |
| 6 | $ 4500 - 5000 CAD |
| 5 | $ 5000 - 5500 CAD → [Joelette](http://www.joeletteandco.com/en/exclusive-manufacturer-of-the-joelette-all-terrain-chair/joelette-twin-with-two-wheels-for-more-stability/) |
| 4 | $ 5500 - 6000 CAD |
| 3 | $ 6000 - 7000 CAD |
| 2 | $ 7000 - 8000 CAD → [TrailRider](http://www.bcmos.org/trailrider.html) |
| 1 | $ 8000 - 9000 CAD |

**Power Calculations**

* The rolling resistance that can be expected from the device is ~10N (a generous estimate based on the data from [this article](https://www.rehab.research.va.gov/jour/2015/527/jrrd-2014-10-0235.html) [Table 4])
* Based on [this article](https://ocw.mit.edu/courses/edgerton-center/ec-711-d-lab-energy-spring-2011/intro-energy-basics-human-power/lab-1-human-power-homework/MITEC_711S11_lab1_pedal.pdf), the average power output sustained for one hour of a healthy person through foot pedals is 200 W.
* Estimate that arms can output 30% of the power of the legs, at 60W for one hour.
* A device would need a mechanical efficiency of at least 17% to generate enough power to overcome rolling resistance for one hour at 1 m/s.
* For an 80kg person, the force required to overcome gravity on a 5° incline is ~68N
* In total, this is 78N. Moving at 0.5 m/s this requires a power output of 39W.
* Assuming a 5 minute climb, using the same power output assumptions as above, a mechanical efficiency of 43%, probably not possible independently.
* Would even require 33% ME for a 1 minute climb on 5°

**Rejected Evaluation Criteria**

**Simplicity**

Simplicity will be assessed based on our team’s knowledge of mechanical systems. Given the tight time constraints of the project, it is given a substantial weight of 15%.

**Stability:**

Stability is quantified based on the maximum roll angle that a chair can sustain before tipping over. The tipping angle is a function of the wheel width and the height of the Rider’s center of gravity.

In terms of high-severity failure modes, tipping is estimated to be the most likely. However, we chose to remove it as an evaluation criteria in the WDM because the location of the COG and the wheel width can be easily varied (with the exception of the one-wheel concept). This design choice will instead be explored in the detailed-design phase.

**Durability**

Durability is nearly impossible to accurately assess before detailed design, so it will be evaluated based on our team’s knowledge of the durability of mechanical systems (eg. brakes, pedals, chains) that appear in each concept.

The weight that the durability criterion is given in the WDM is low (5%) to reflect the large uncertainty that comes with it. Durability is also intertwined with simplicity.

**Rider Comfort**

Rider comfort will be evaluated based on the criteria from [this article](https://www.worksafenb.ca/docs/OFFICEEdist.pdf). The ten criteria of a comfortable chair are shown in the table below.

|  |  |
| --- | --- |
| 1 | Backrest’s shape promotes natural spine curve of the lower back |
| 2 | Backrest is adjustable vertically |
| 3 | Backrest is adjustable horizontally |
| 4 | Backrest’s material promotes firm lumbar support |
| 5 | Buttrest is adjustable vertically and horizontally |
| 6 | Buttrest is supported by at least a 5-point base |
| 7 | Buttrest is angled such that the thighs are horizontal with 90°-110° angle with hips |
| 8 | Armrest is angled so that the elbow bends at 90°, forearm is parallel to buttrest |
| 9 | Armrest is adjustable vertically and horizontally |
| 10 | Feet are fully supported and parallel to buttrest |

**Portability**

The portability of the device is quantified based on the size of vehicle that it can be transported in. Given that most vehicle trunks are shaped like rectangular prisms and the vehicle websites merely supply the trunk volume, the trunk dimensions of several common vehicles are estimated as shown below.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Width | x |  | V (ft³) | V (m³) | x (m) | Model |
| Height | x |  | 9.2 | 0.26 | 0.51 | 2017 SmartForTwo |
| Length | 2x |  | 15 | 0.42 | 0.60 | 2019 Honda Civic |
| Volume | 2x³ |  | 25 | 0.71 | 0.71 | 2019 Nissan Kicks |
| Volume breakdown | |  | 38 | 1.08 | 0.81 | 2019 Toyota Rav4 |
|  |  |  | 46 | 1.30 | 0.87 | 2019 Toyota 4Runner |
|  |  |  | Sample Trunk Volumes | | | |