ADAPTIVE TOOLS
HUMAN POWERED SYSTEMS

CARMEN LIU

HARAMBEE >>> PULLING TOGETHER

ACKNOWLEDGEMENTS

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I would like to thank the many people who have taken their time to teach and listen and their bountiful support and involvement in this project.

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FOREWORD

Adaptive tools - Human powered systems

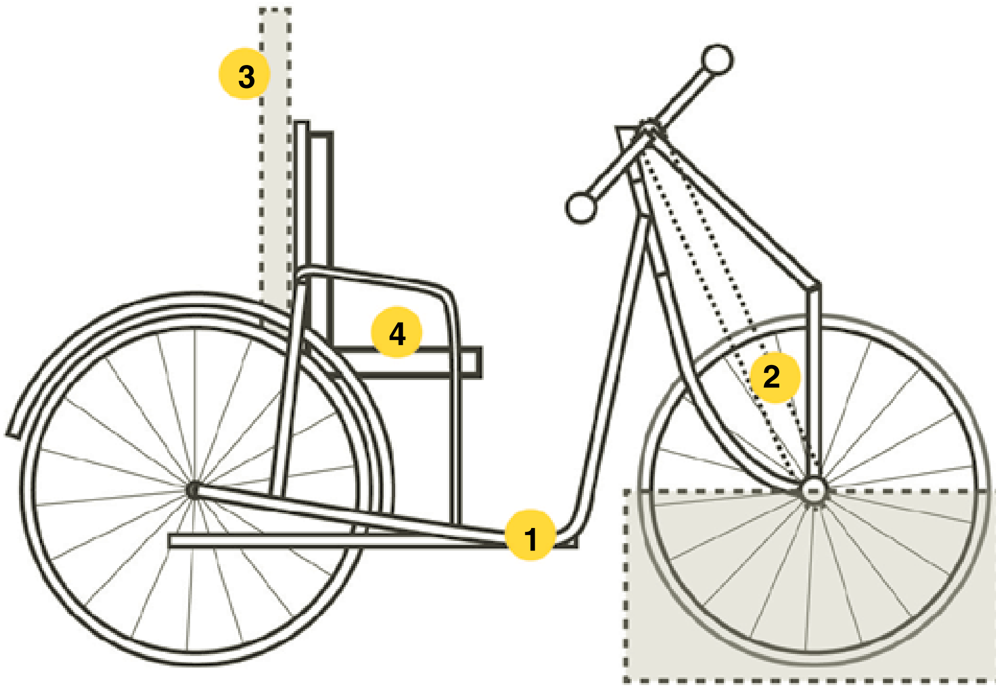
This project addresses design innovation for disability. Kasese is considered to be one of the poorest districts in Uganda. The current wheelchair tricycle is locally produced and provides persons with disabilities increased mobility and allows them to be independent and travel to the market. It also means access to education and employment, making it easier for them to participate in society and lift themselves out of poverty.

However, technically it is possible for the tricycle to provide more than mobility and be used to power other devices. The challenge is designing something that fits comfortably within the constraints of the local area, materials, and workshop capacity. However, doing so will open up opportunities for many adaptations and enhance livelihood.

This report outlines the research process based on addressing the current situation and designing an opportunity from there. Outside of cultural and environmental factors, explorations into the technical aspects of the project form the foundation of the final concepts. Through perusing the competitive landscape and set factors, a vision for the design is positioned with a set of reasonable metrics to evaluate the performance and success of the design.

THE TEAM

Harambee



FRAME AND MANUFACTURE

Tools and fixtures to simplify manufacturing

DRIVETRAIN AND TOOLS

Optimise the tricycle's drivetrain to power tools

BUSINESS OPPORTUNITIES

Use the tricycle to operate small businesses

MOBILITY BEYOND THE TRICYCLE

Enabling mobility outside of the tricycle

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EXECUTIVE SUMMARY

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Project background

Problem statement

A tricycle is able to increase the independence and mobility of the user.

The problem in focus is ways to create adaptive tools based on a human powered system by utilising the tricycle as a source of power for tools for tasks.

Project objectives

Designing for, with, and in Kasese, Uganda.Together with CanUgan, the project's overarching objective is to promote independence through mobility and to take an innovative hyper-local approach to design with and for persons with disabilities in Kasese.

The goal of the design is a system with the potential for a collection of tools adapted to the hand pedalled tricycles in Uganda that emphasizes that disability is not inability. Users would be able to easily set up the system and utilize it to perform specific tasks. Through this, we can create opportunities for income growth and community participation.

To illustrate this point, a small scale mill was used as a case study.

We (people with disabilities) need ***innovation****, but we need help.*

- Fatuma Acan, co-founder of MADE Uganda

Kasese District Union of Persons with Disabilities head office in Kasese, Uganda

CONTEXT

Project timeline

sept 2012
project begins

oct 2012
research

nov 2012
communication with kasese and experts

DEC 2012
conceptualisation

JAN 2013
prototyping

FEB 2013
trip to uganda - research, testing and validation

MAR 2013
final design

CONTEXT

Opportunity

The current wheelchair is locally produced and allows PWDs to be independent. With increased mobility, they can travel to the market, start businesses, visit friends, and help out with basic everyday family tasks. These open up pockets of revenue for them. The tricycle itself also has many areas to address from a technical perspective like manufacturing and materials to safety and mechanics of the device.

Kio, a self-taught welder in the rural Ugandan district of Kasese, recently began manufacturing these tricycles for people with disabilities in his community. From the first to the last, the tricycle has gone through different variations, each one suited to the specific needs of the user.

It is possible to take these tricycles --something they already own, to extend beyond mobility and be used to power other tools and/or devices to improve livelihood and create employment. The challenge is designing something that fits comfortably within the constraints of the local area, material, and workshop capacity.

At the workshop, Kio's helpers cut and weld sheet metal together for a prototype.

EXPLORATION

Environment

History

Due to years of civil war in Uganda, along with the misfortunes of poverty and poor health care, there is a significantly high percentage of people with disabilities in the country. Kasese was a focal point of insurgencies and conflicts and as a result, it is one of the poorest districts in Uganda.

Geography

Kasese is located in Western Uganda with a population of over 600,000. It is situated in the Western Region on the border of the Democratic Republic of Congo (DRC).

Neighbourhood

The village is built up of huts on plots of land that also contain small farms that feed the families that tend to them. Without plumbing, cooking is done outside and fetching water is a daily chore often performed by children.

Terrain

Many roads are not paved so the terrain is very rough and difficult to traverse, especially in the rainy season.

People

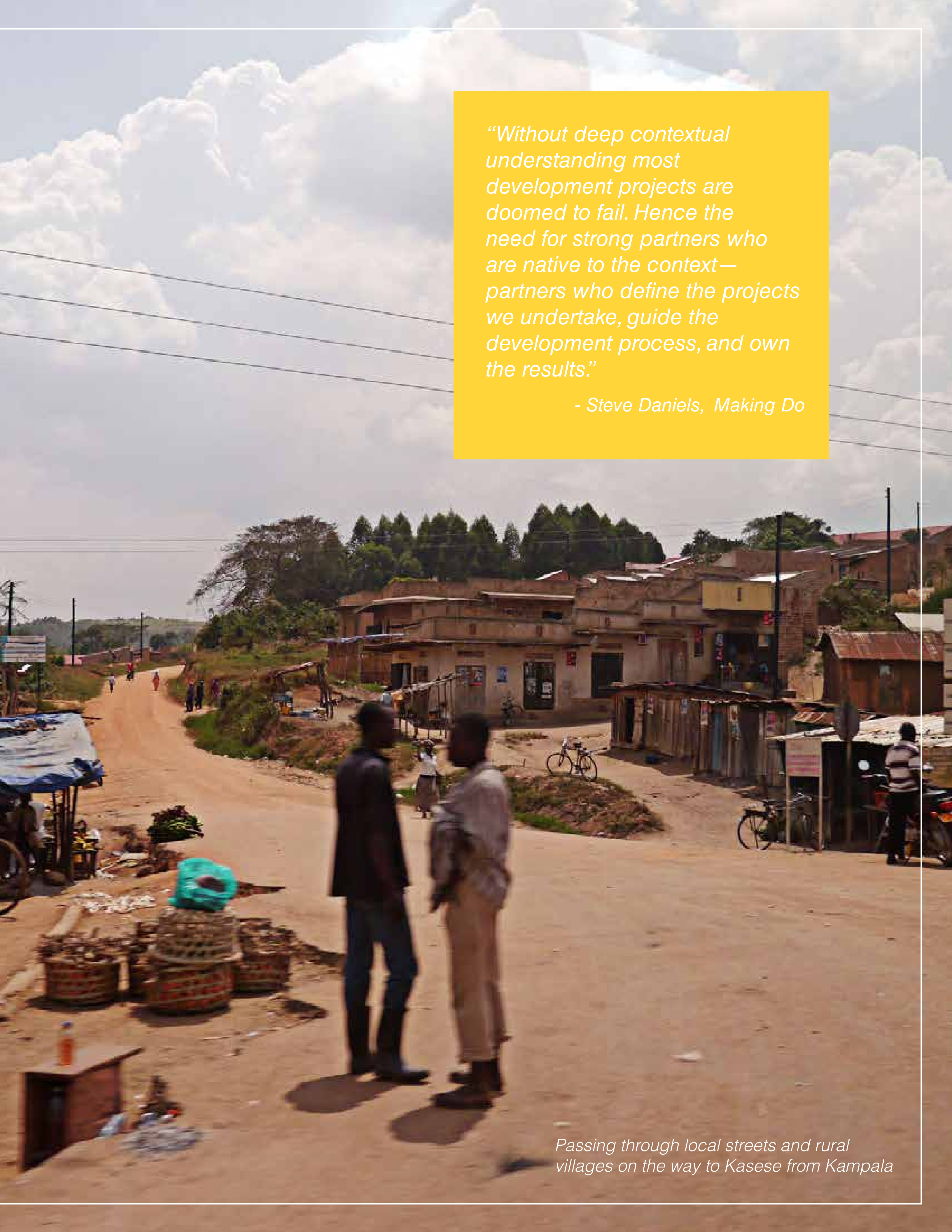
The population of Uganda is very young, with over half the population under 14. Families tend to be very large, having six or more children. Although English is the official language, literacy rates are low.

Climate

Kasese has two rainy seasons that come between March to May and August to November.

Culture

The district is mainly agricultural with over 85% of the people being peasant farmers who depend on subsistence farming for their livelihood. The people are friendly and always willing to give a family member or friend a hand.



"Without deep contextual understanding most development projects are doomed to fail. Hence the need for strong partners who are native to the context—partners who define the projects we undertake, guide the development process, and own the results."

- Steve Daniels, Making Do

Passing through local streets and rural villages on the way to Kasese from Kampala

EXPLORATION

Research

The research phase involved looking into many aspects relating to the user and his/her lifestyle. Gaining context to set a framework to design within was important.

Research was done in different areas with the goal of finding opportunities within the current situation, environment and culture. This included many expert consultations, reverse engineering, skype interviews, and competitive product analysis.

Questions such as who or what, and where are we designing for? were raised throughout the project aiming to identify key positions that would make the project and idea relevant for our end users in Uganda while doing the work in Canada.

Within this phase, many power transfer techniques were investigated and one involving a direct engagement with the tricycle was selected.

What are the goals of our users?

Because the goals of the users should be a part of the product's goals too

How are these tricycles being used today?

Is it already used for business? How? What are other local innovations related to the tricycle like?

Who are the right users?

Because perhaps this product is not something for everyone

Why are they in poverty?

This relates to capacity building and why they do the things they do as well as gaining an understanding for how things work differently in Uganda.

In Karambe, a tricyle wheelchair user explains how he does business transporting goods to the DRC

IN KASESE

Population: 600,000 persons

85% depend on subsistence farming for livelihood

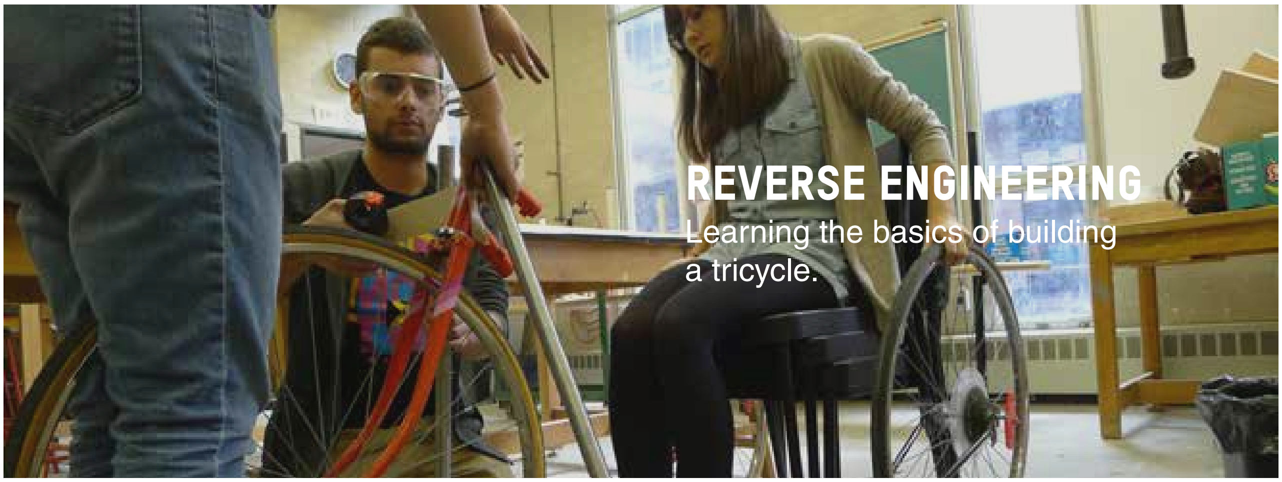
IN UGANDA

87% live in rural areas

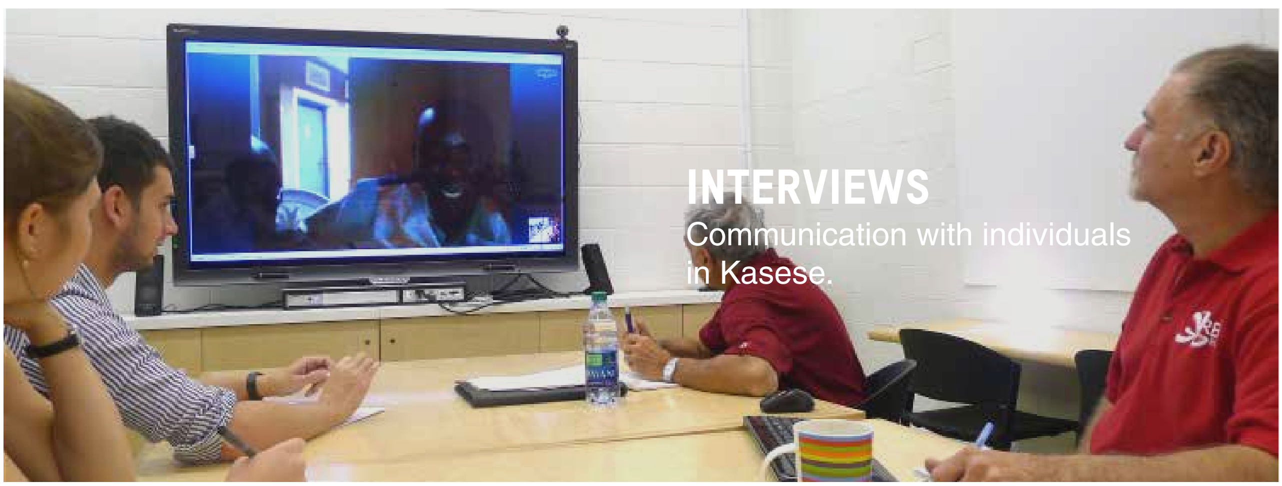
75% are living under $2/day

Over 5 million people live with some form of disability

EXPLORATION



REVERSE ENGINEERING
Learning the basics of building a tricycle.



INTERVIEWS
Communication with individuals in Kasese.

EXPERT CONSULTATION
Learning from the experience of experts.

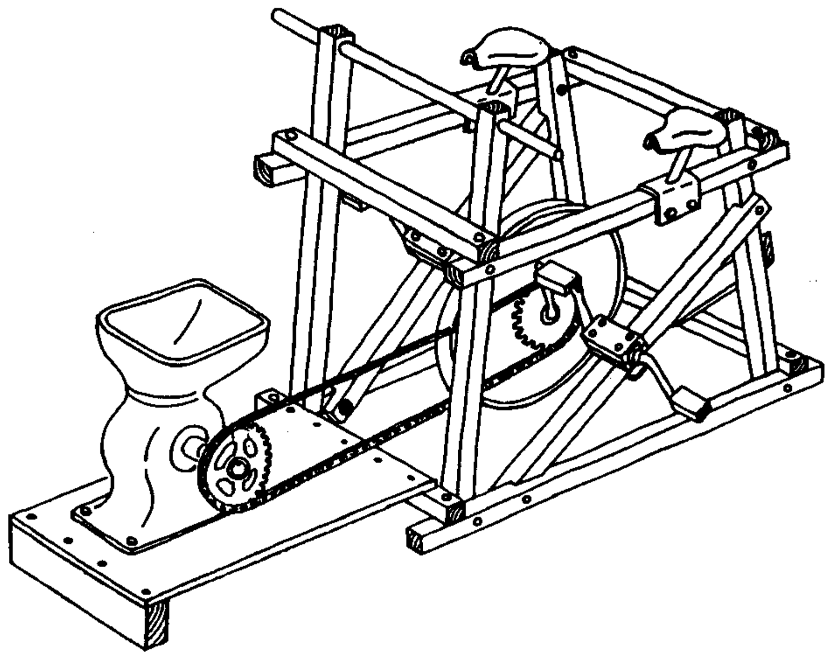

PRODUCT ANALYSIS
Looking at local bicycle machines


KNOWLEDGE TRANSFER
Visiting bicycle shops and sharing ideas.


CULTURAL IMMERSION
Experiencing markets and daily life in Kasese Uganda.

EXPLORATION

Literature



Extracts from Bicycling Science, Wilson, David G., 2003

Power Levels

To be able to continue pedaling over an extended period, a person must be able to keep cool--whether because the ambient temperature is low enough, or because there is adequate breeze.

It is essential that an individual pedaling such a stationary device in hot or humid conditions be provided with shade from the sun, plenty of water, and preferably some sort of fan. A portion of the power that the pedaler is producing can be used to drive this fan; this is an efficient use for the power, since it will help prevent damage to the pedaler's health.

Pedalling Rate

However, people can produce more power--or the same amount of power for a longer time--if they pedal at a certain rate. This rate varies from person to person depending on their physical condition, but for each individual there is a pedaling speed somewhere between straining and flailing that is the most comfortable, and the most efficient in terms of power production.

A simple rule is that most people engaged in delivering power continuously for an hour or more will be most efficient when Pedaling in the range of 50 to 70 revolutions per minute (rpm).

Crank Length

The normal crank on an adult's bicycle is 165 to 170 millimeters (mm) long. However, people remain able to produce near maximum power output at any crank length from between 165 and 180 mm, so long as they have a period to practice pedalling at the new length.

Broadly speaking, applications of pedal power are possible when the power level required is below a quarter of a horsepower (that is, below about 200 watts). Common applications of stationary pedal power include pumping water, grinding grains or metals, shredding, or threshing.

The Dynapod

It is frequently cheaper in initial and maintenance costs to use a properly designed and constructed dynapod.

A dynapod is a portable pedaling device that consists of a stand, saddle, handlebar, pedals, and sprocket wheel. Dynapod power varies according to the size and fitness of the operator and the length of time spent pedaling.

There are three kinds of dynapods:

1. A one-person dynapod that utilizes belt drive. It can be built either with or without chaindrive.
2. A two-person dynapod that can be pedaled either by one person at a time, or by two people together. It is also possible to fit a special adaptor so that a direct shaft drive leads off the unit and powers a flour mill or other machine.
3. A one-person dynapod that has belt drive, chain drive, and direct drive. (very similar to above)

Other pedal power applications include:

Cassava graters, coffee pulpers, coffee/grain hullers, cracking of oil palm nuts, fiber decorticaters--sisal, manila, hemp, etc., winches or hoists, balers, potter's wheels, tire pumps, flexible shaft drive for portable grinders, saws, etc.

EXPLORATION

Competitive product analysis - Bicycle machines

1 MayaPedal, Blender

3 MayaPedal, Dedicated Tricycle

5 VAAP, Farming mill to clean grain

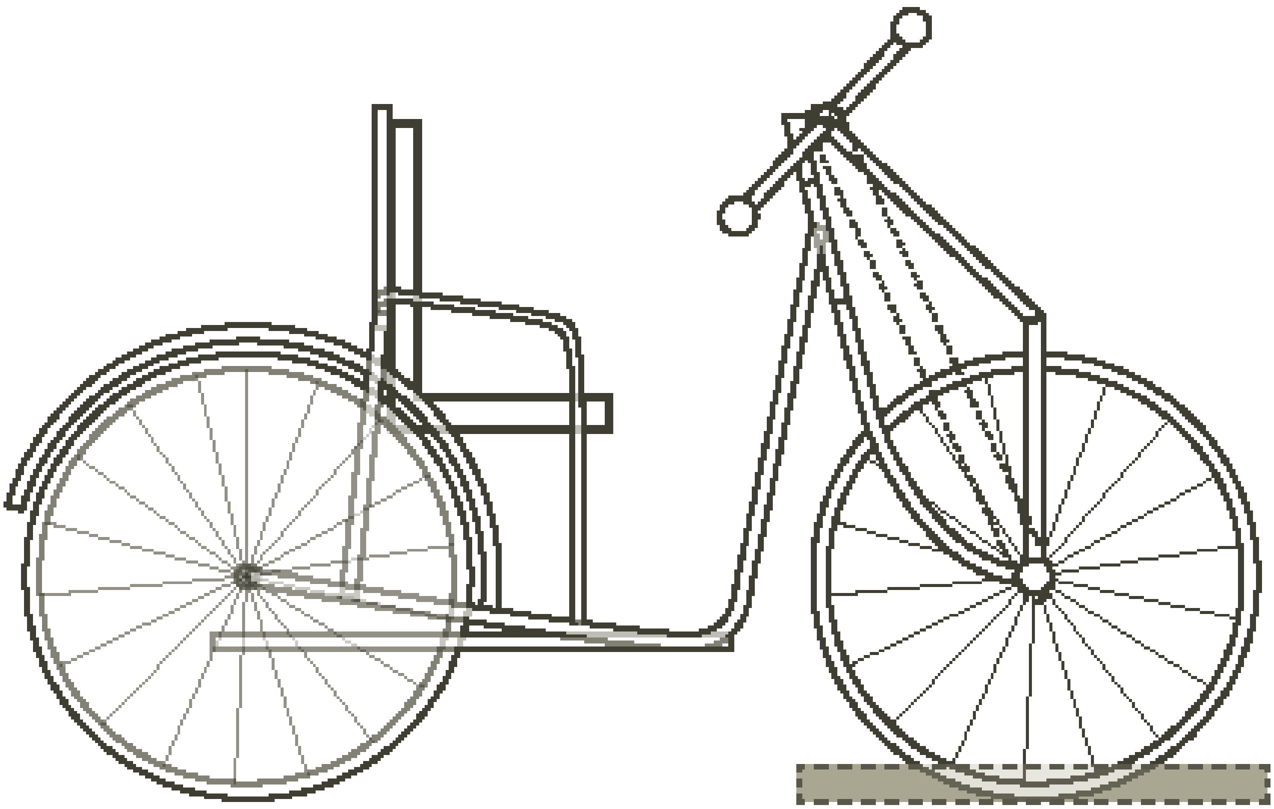
2 Winterbikes, Knife Sharpener

4 SpinCycle, Washing Machine

POINTS OF INTEREST

- Rotating an object perpendicular to the wheel or along (see 1, 4)
- Multiple gears and chains, or relocating the chain (see 2, 5)
- Flywheel (see 3)
- One machine can adapt to interchangable parts and utilise a single gear
- Pedal power is optimal for high power range. Whereas, hand crank power is fit for the lower power range -- for agriculture, construction, water pumping, and electrical generation.

VISION

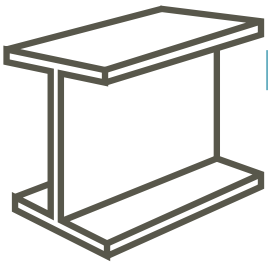


The focus is on creating an appropriate mechanism to transfer power without adversely affecting the tricycle's performance.

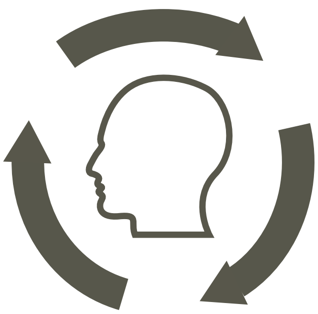
The end result will necessarily solve a problem as much as it addresses an opportunity to improve livelihood.

VISION

Metrics

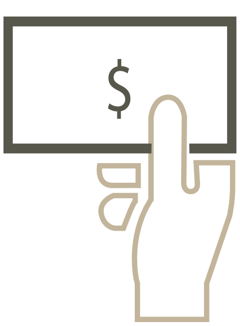


STRUCTURAL RIGIDITY



USE CYCLE

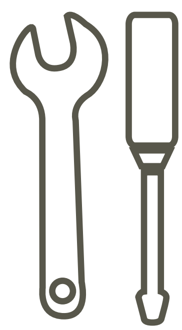
SIMPLE MANUFACTURE



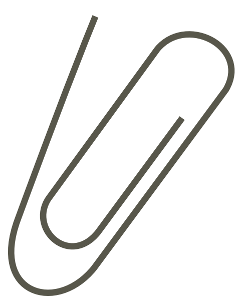
ECONOMIC OPPORTUNITY

ERGONOMICS

CULTURAL CONTEXT



REPARABILITY

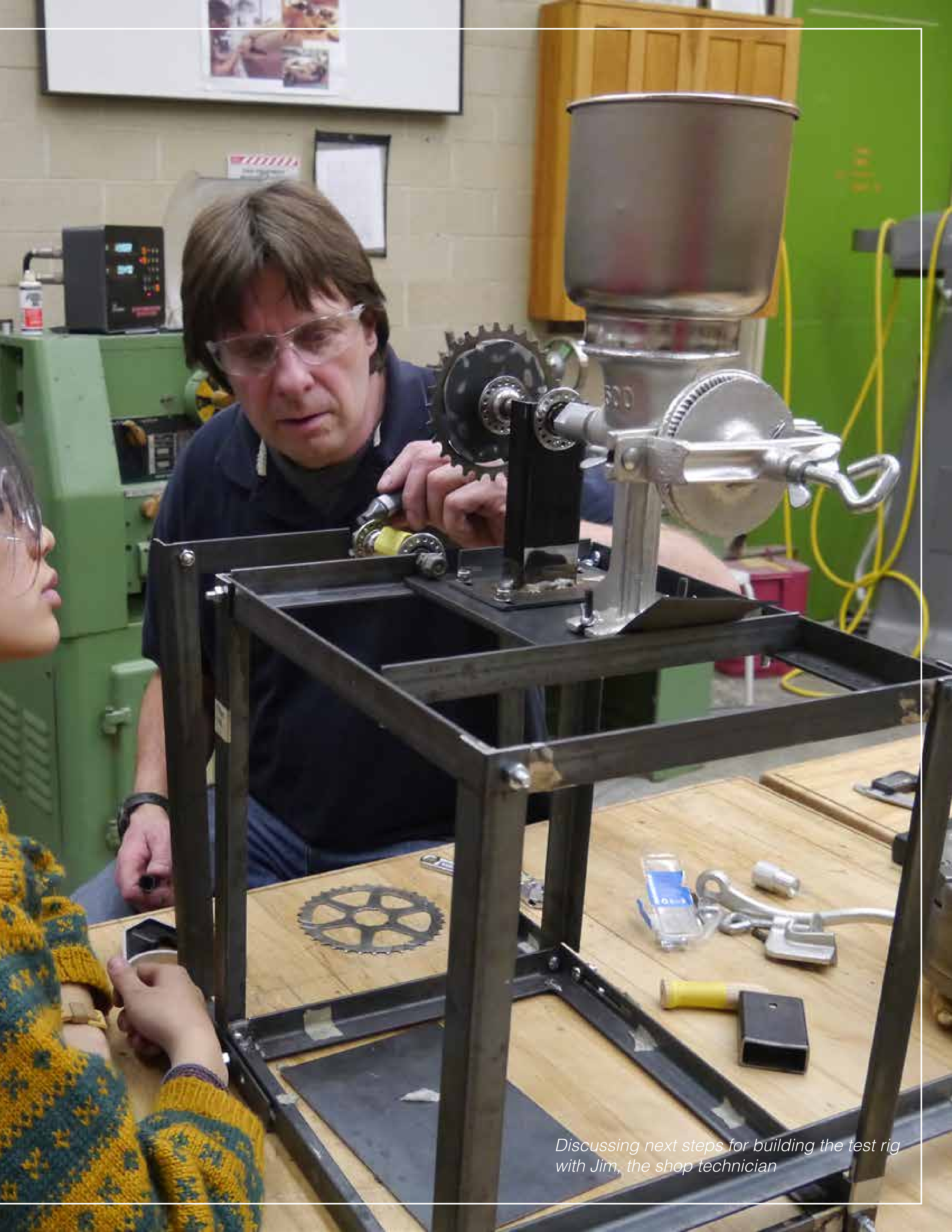


OPEN DESIGN

DESIGN DEVELOPMENT
Concepts

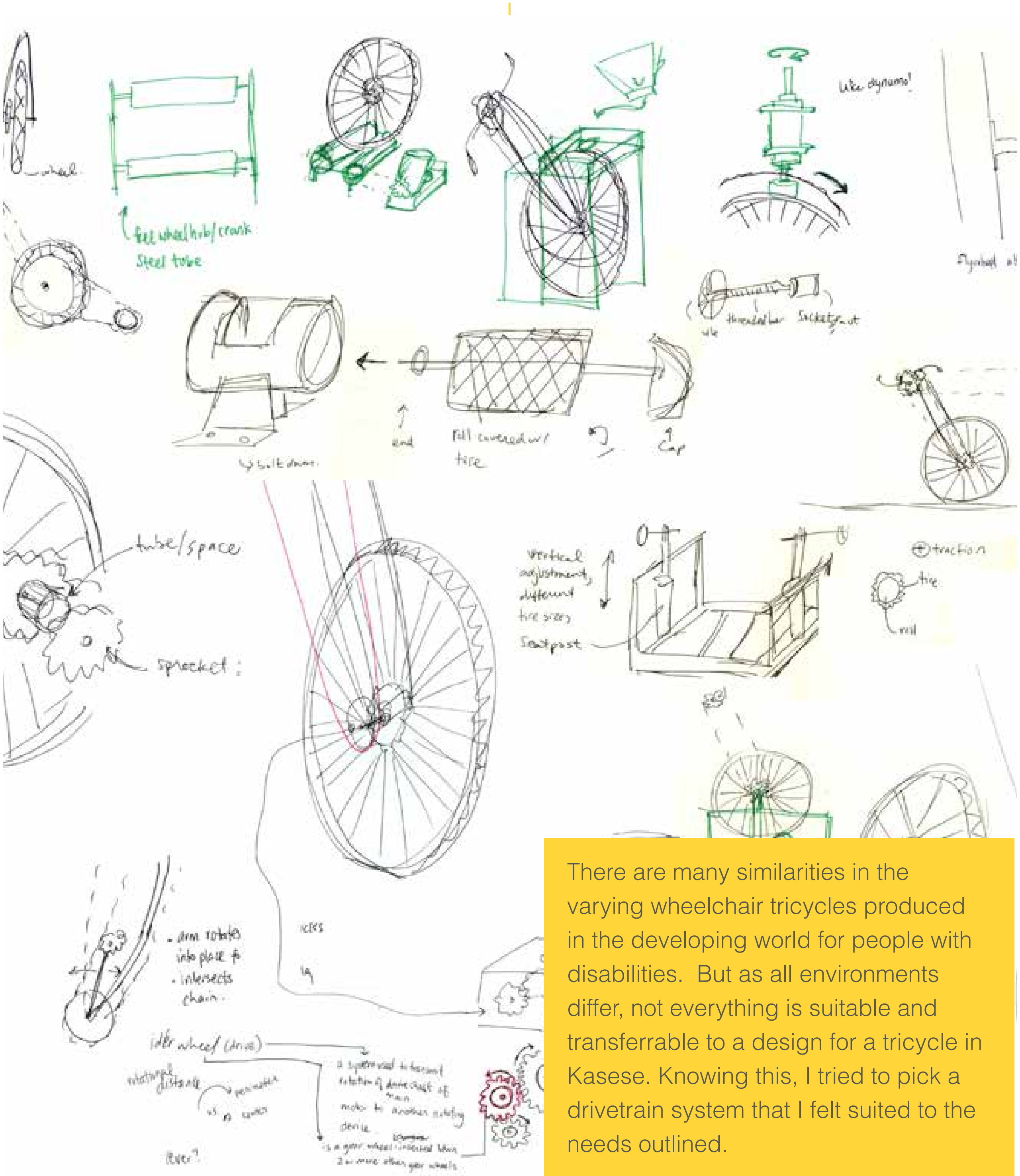
The design involved going through a variety of techniques that allowed for power transfer from the tricycle wheelchair to an object. The focus was to find a balance between performance, low cost, local parts, and usability for a disabled person. Finally, a method that did not involve multiple complex parts to power a small scale mill and was easy to use was chosen.

A series of quick mockups and sketches helped clarify the concept.



Discussing next steps for building the test rig with Jim, the shop technician

DESIGN DEVELOPMENT



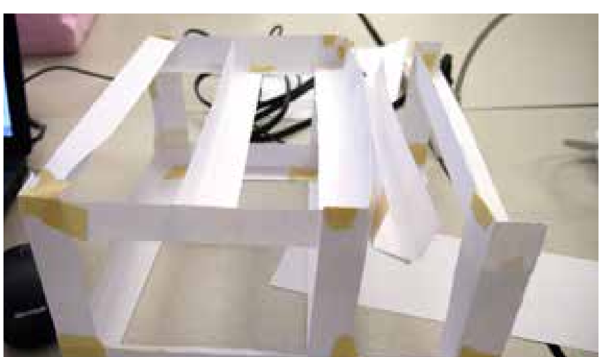
There are many similarities in the varying wheelchair tricycles produced in the developing world for people with disabilities. But as all environments differ, not everything is suitable and transferrable to a design for a tricycle in Kasese. Knowing this, I tried to pick a drivetrain system that I felt suited to the needs outlined.

DESIGN DEVELOPMENT

Prototyping

There are many 'bicycle machines' out there as well. However, none have I seen utilising hand pedal power or tricycles. This is most likely due to the fact that more energy can be extracted from the weight of one's body through the feet and therefore it is more efficient. Also, majority of these bicycle powered machines are more machine than bicycle and all of them use foot pedal power. However under the assumption that the fundamental concept is the same, it in my interest to adapt that knowledge to the hand pedaled tricycles and enable the technology to less able bodied individuals.

Engaging sprocket to the chain



A quick frame mock-up

Using bicycle parts

A mill and gear connection

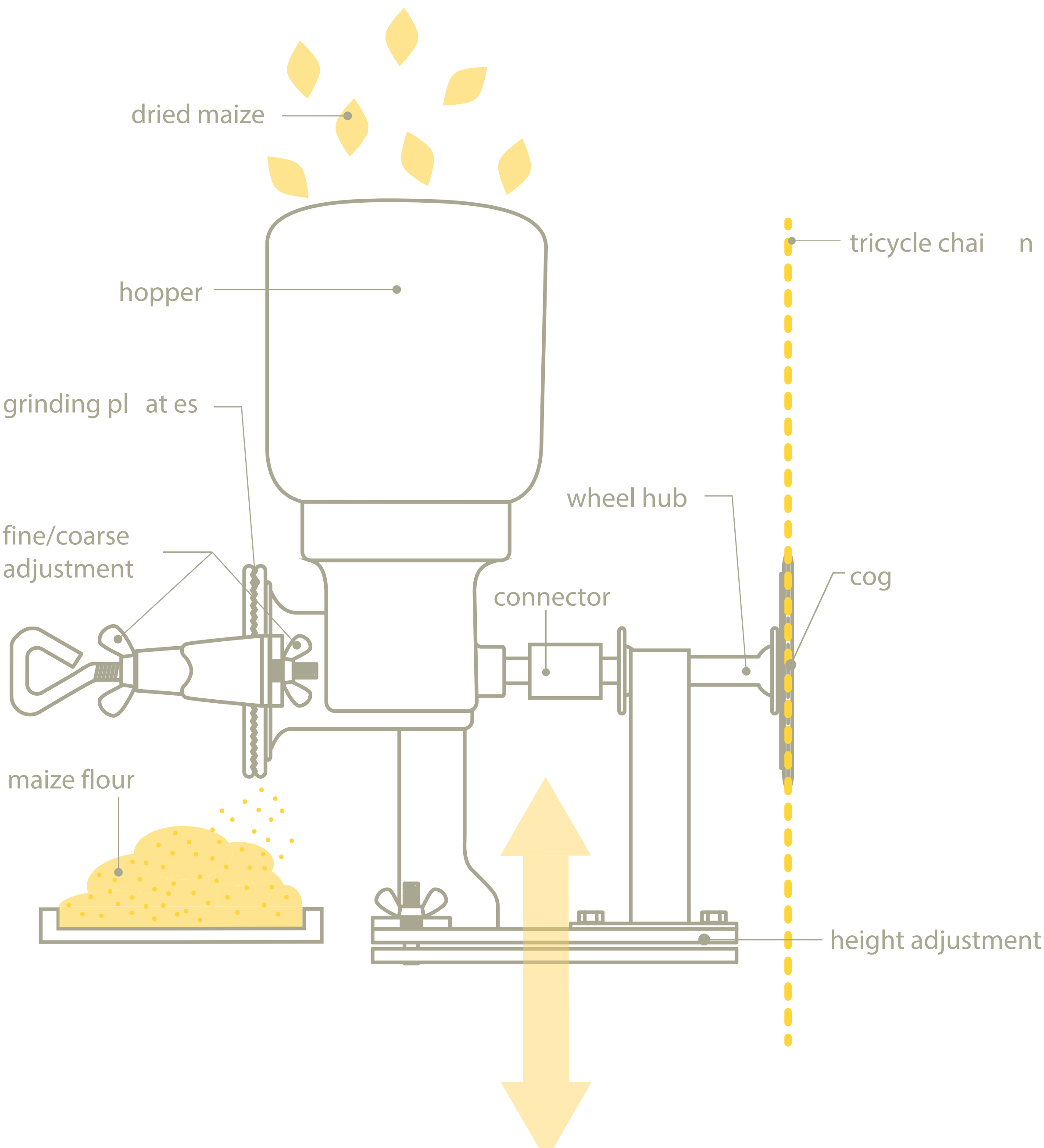
TESTING

A working model was designed and brought to Uganda for testing. The testing phase was mostly executed in Uganda with end users using the working model and providing feedback while making changes in real time. Two areas of focus in this phase were the mechanics and the usability. Working closely with Kio, the manufacturer, we discussed ways to fix issues for future iterations. The results gathered from testing identified critical features that drove the final design.

Test subject reaches to add more groundnuts to the mill

TESTING

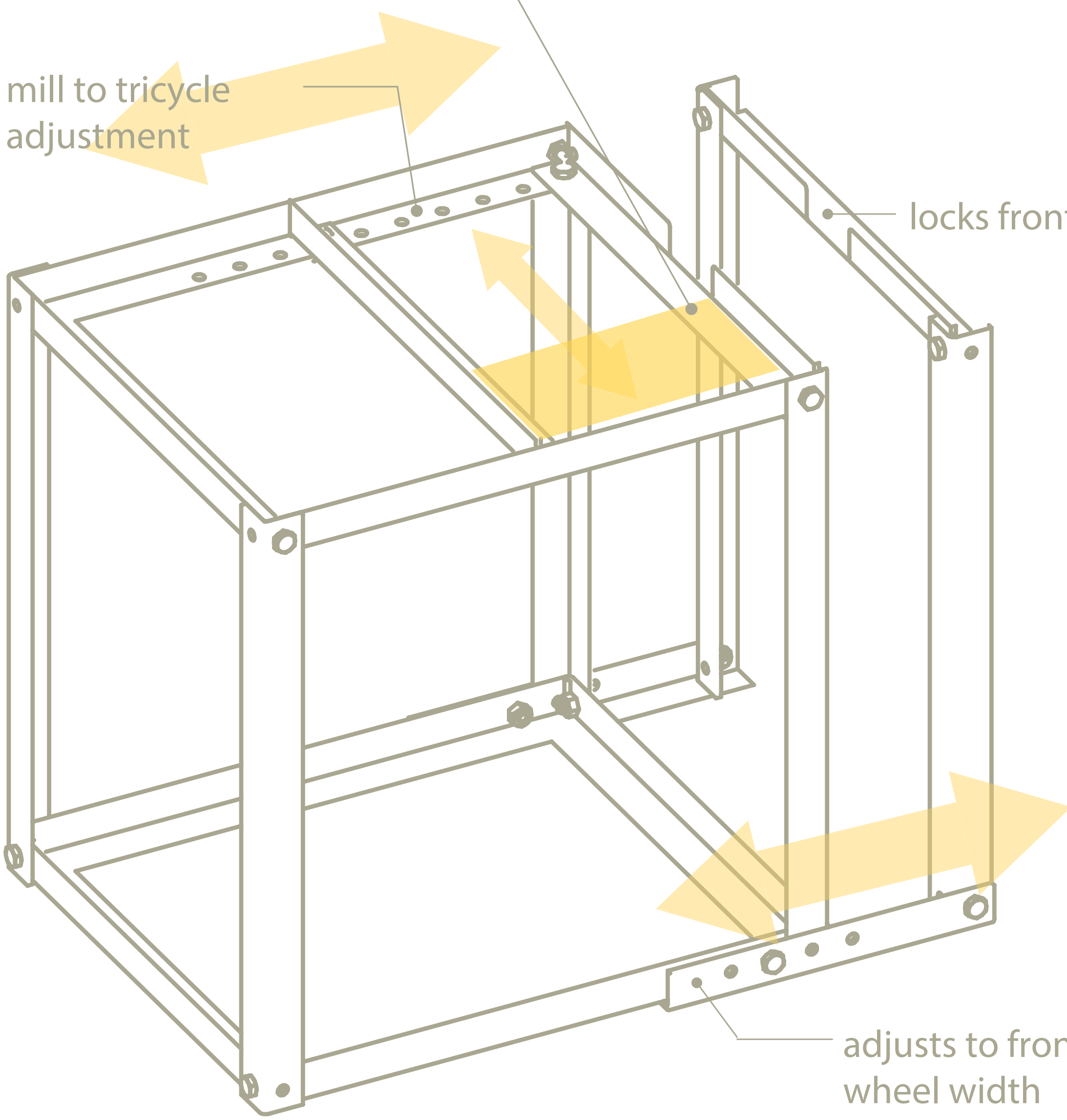
Test parts



HOW THE MILL WORKS

Maize is placed in the hopper and the chain engages with the cog which spins a central axel and pushes the maize through the grinding plates at the other end, producing flour. The purpose is to test the ease of use of the grain grinding process for the user.

TESTING



THE SUPPORT STRUCTURE

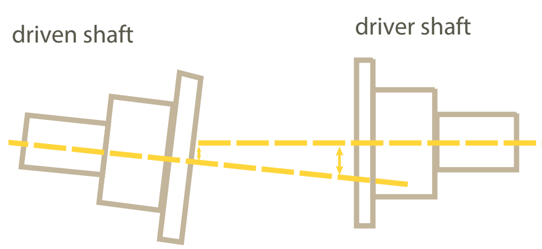
This structure elevates the front wheel and holds the mill. It is constructed out of angle iron and is adjustable in the XY axis to account for different types of tricycles. This was built to be highly compact for travel purposes as well as adjustable to address multiple options for the tricycle in Uganda.

TESTING

Areas to Address

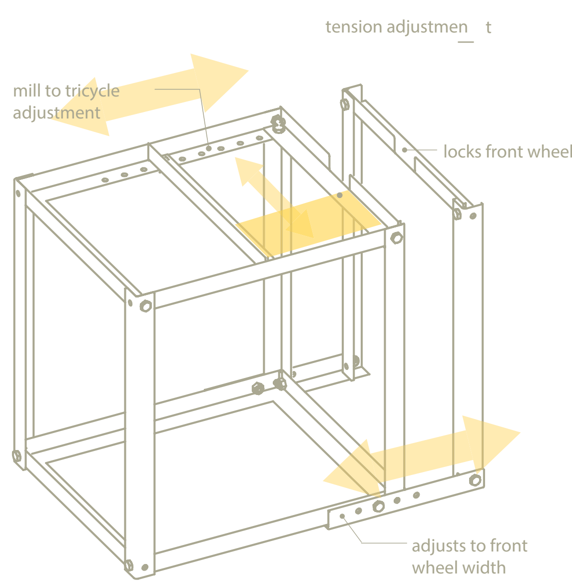
MECHANICAL

ISSUES	RESOLUTION
1. Shaft alignment	Low tech universal joint
2. Part instability	
3. Sprocket alignment	Ensure mill plate is parallel to chain
4. Weak sprocket	Thicker steel weld support
5. Gear slippage	Increase chain length between gears for increased tension



USABILITY

ISSUES	RESOLUTION
1. Handles	Usable for one handed or two handed, or seated on the side
2. Transport	Fits on the back of the tricycle, ties on with rubber
3. Output	A guide plate to direct grind towards bowl
4. Output Storage	A height adjustable tray for depth (volume) and enough surface area to comfortabley place a plate or bowl
5. Setup	Wing nuts and washers for an easier grasp and dispersed load



TESTING

Co-design process

BUILDING LOCALLY
Rebuilding a working prototype at Kio's workshop

USER FEEDBACK
Testing with users and making changes

FIRST ITERATIONS
Initial improvements within the time and capability of Kio's shop

FINAL DESIGN

The final design was based on iterations from a previous model built in Uganda with Kio. The key part is being able to take power off the tricycle and transfer it to something else that doesn't require precise parts to function. It is also supported by an opportunity for business and simple manufacturing. As the design is made to be adaptable to different tools, it is purposely left open for local innovation.

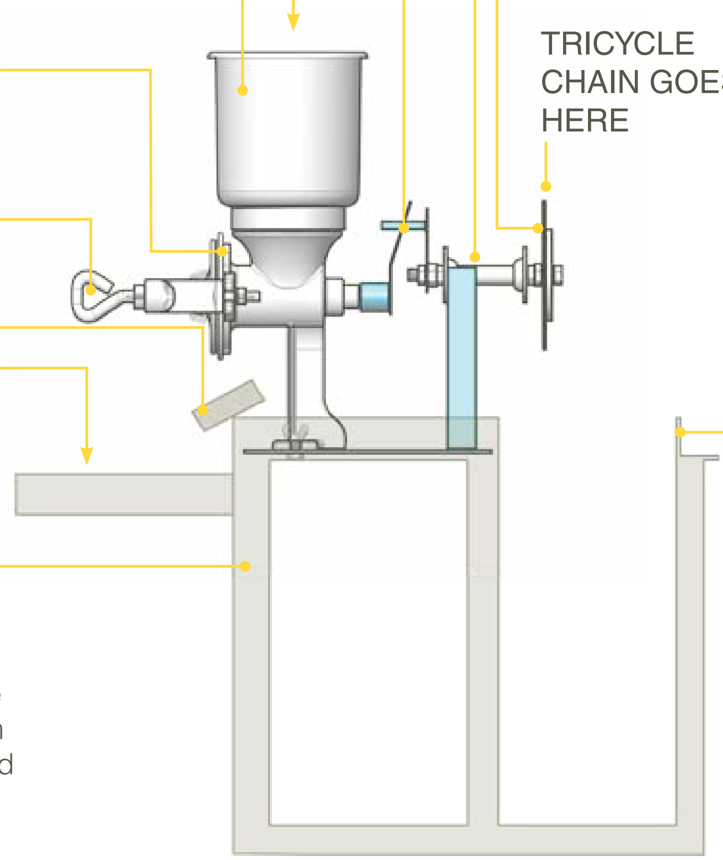
The final model

FINAL DESIGN

List of parts

THE GRINDER

Nuts or grain is placed in the hopper while the tricycle's chain engages with the cog which spins a central axel that pushes the nuts through the grinding plates at the other end, producing fresh ground for food and sauces.



THE SUPPORT STRUCTURE

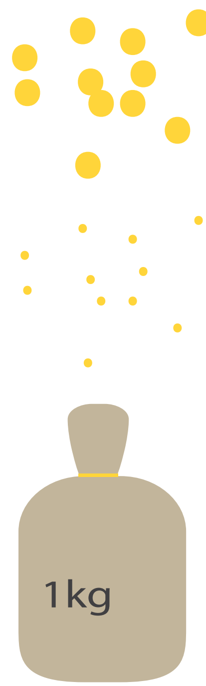
This structure elevates the front wheel and holds the mill. It is constructed out of angle iron and is manually adjustable to and from the chain. This ensures good alignment and tension for different types of tricycles.

FINAL DESIGN

Business Opportunity

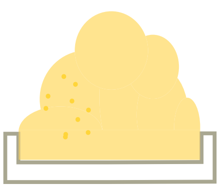
SUPPORT

With the tricycle, business is portable and can travel to other nearby villages



MARKET PRICE

Generally, nuts are purchased for 3000 UGS/kg and can be ground and sold for 4000 UGS/kg*



POTENTIAL CUSTOMERS

Customers who purchase stock pre-ground nuts
Price: 4000 UGS

POTENTIAL CUSTOMERS

Customers who bring their own supply of nuts to grind
Price: 1000 UGS

EARNINGS

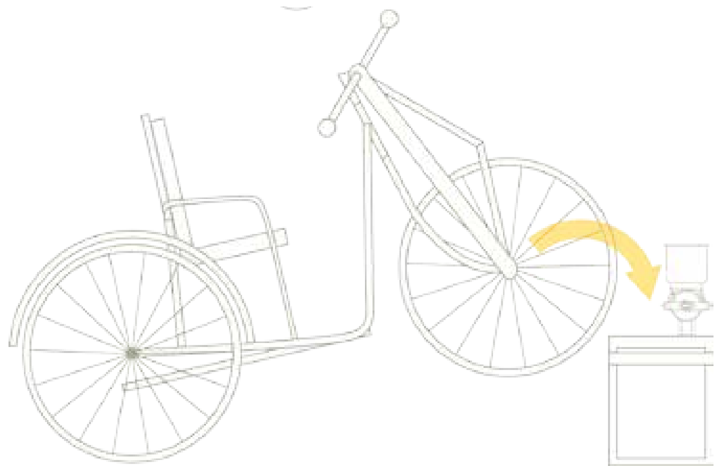
Net profit: 1000 UGS/kg
Average sales: 5kg/day

FINAL DESIGN

Use cycle

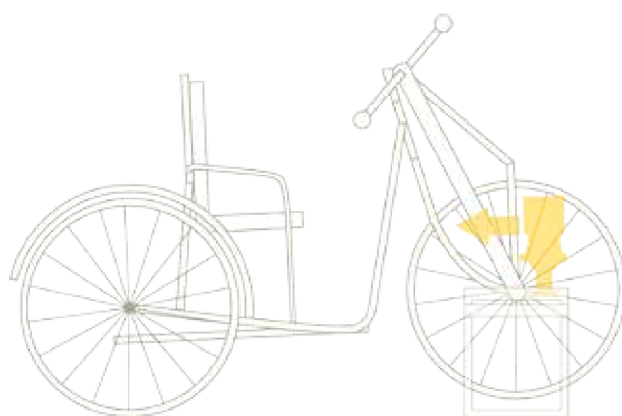
1

The user drops the tricycle into a slot that holds the front wheel in place.



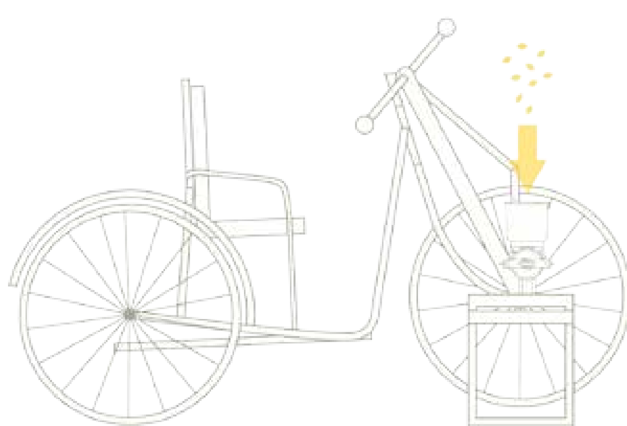
2

The user pushes the mill in towards the chain of the tricycle for tension, making sure it is aligned.



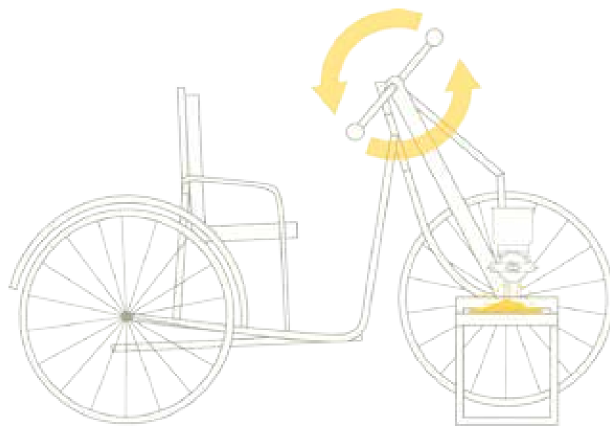
3

Nuts or grain is placed into the hopper.



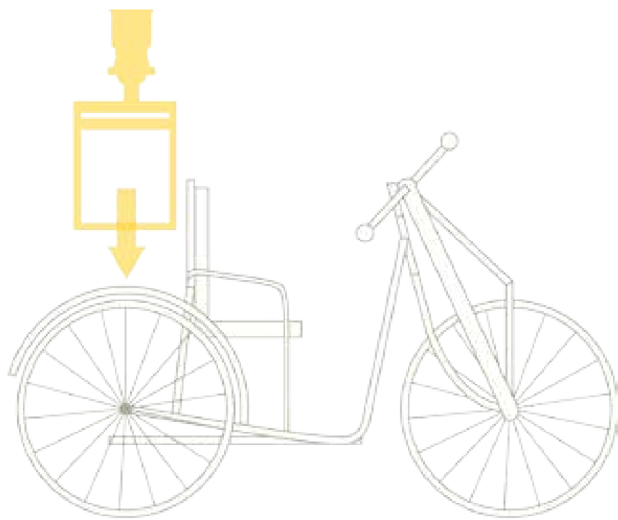
4

Getting back into the tricycle, the user pushes the cranks in a forwards motion to power the mill.



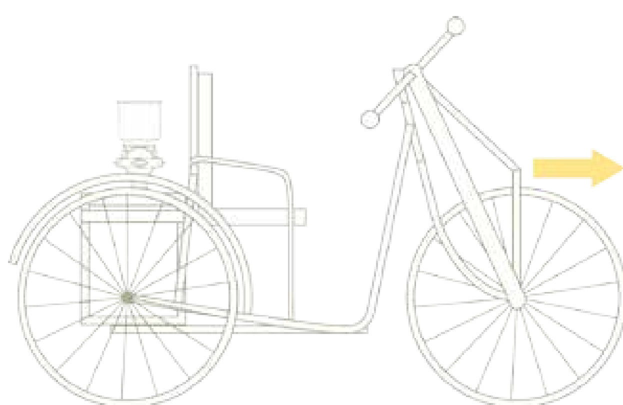
5

Once finished, the user separates the tricycle from the frame and secures it to the back of the tricycle with rubber straps.



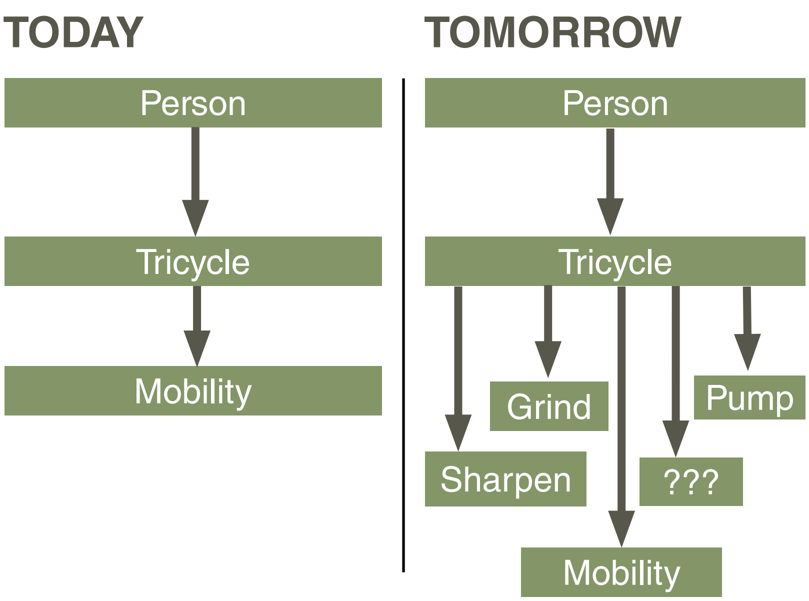
6

The user is all ready to go!



CONCLUSION

Adapting a mill to a tricycle is just the beginning. The key part is in the joint that connects to the tricycle's drivetrain. This makes it possibile to operate any tool that can be adapted to a similar system. Thereby increasing social mobility.



Gear engaged with a tricycle chain