

# HUMAN-POWERED WASHING MACHINE PROJECT

## “EZ NCORO”

### ABSTRACT

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#### PATH STATEMENT

Washing clothes is a time-consuming and labor-intensive activity for the women of D’kar. It often takes them a full day each week to clean their family's clothes. Water scarcity further complicates the process. In addition to the usual challenges of washing and rinsing clothes by hand, many women must walk a kilometer or more each way to fetch water from a community tap.

Our team created a prototype of a simple, low-cost, human-powered washing machine and wringer to reduce the time and effort needed to wash clothes and conserve water in each step of the process. By using this product, the women of D'kar can spend their extra time on other household chores, with their family/community, or generating income.

#### KEY FEATURES

- Human-Powered
- Built with Locally-Sourced Materials
- Low-Cost (Purchase & Maintenance)
- Simple & Easy to Use
- Water Conscious

### CONTEXT

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#### COMMUNITY OVERVIEW

D’kar, a small village just north-east of Ghanzi Township in the Kalahari Desert of Botswana, was formed in the mid-1960s by the D’kar Reformed Church and is currently administered by the Kuru Family of Organizations and the Kuru D’kar Trust. It’s located on a private farm.

Though the community is not formally recognised by the local government, the government does try to intervene in propelling development.

Home to a couple thousand Ncoakhoe San (aka San) people, D'kar consists of a number of small plots/homes as well as the church, a primary school, a small clinic, and a couple small stores. The community also operates an art gallery, cultural center, wildlife ranch, and an annual dance festival to bring in tourist revenue.

D'kar has electricity, but like other rural villages in Botswana, suffers from frequent power outages. The majority of homes and buildings in D'kar, however, do not have electricity. Instead, most members of the community use firewood as their main fuel source. In recent years, firewood has been overharvested so has become increasingly difficult to find nearby.

Water is scarce in the Kalahari Desert, so is typically drawn via wells from an underground aquifer. Unlike most villages, D'kar residents are provided free water thanks to an arrangement with the Kuru Family of Organizations and the Kuru D'kar Trust. A few members of the community have their own well and/or a water storage tank on their plot. However, most people in the community need to walk a kilometer or more each way from their family plots/homes to fetch water from the few centrally-located public stand pipes. The amount of water they're able to obtain at one time depends on their mode of transportation. For example, each walker can typically carry 5-10 liters while people with donkey carts can transport much larger quantities of water.

D'kar, like most historically bushman communities, is a patriarchal society currently led by (Chief) Kgosi April Montshosi. Men traditionally provide for their families by seeking employment at nearby farms – work which often requires them to live away from their spouse and children. Women manage their households, raise their children, and care for their entire families. Some of the women also need to take additional part-time or full-time piece jobs to support their families. In addition to the core family, households often also include multiple generations. Typically, the oldest generation supports the younger generations until the younger generation has achieved some measure of financial independence or age begins to degrade the older generation's ability to earn.

The San have a rich cultural heritage. They are resourceful and hands-on people who make their livelihood through agricultural work at the nearby privately-owned farms, a variety of manual piece jobs within the community, or creating/selling a variety of traditional arts and crafts. The community of D'kar predominantly speaks Naro, one of the click-based Khoe languages indigenous to southern Africa. The younger generation, who have typically completed at least primary school, are literate and also able to communicate in Setswana and English. However, the older generation has not had much (or any) formal education so are largely illiterate and can only communicate in their native dialect.

## STAKEHOLDERS

STAKEHOLDER	INTEREST IN PROJECT	PROJECT'S EFFECT ON INTERESTS  ? = Unknown - = Negative 0 = Neutral + = Positive	IMPORTANCE FOR PROJECT SUCCESS  ? = Unknown 1 = Low 2 = Moderate 3 = High	DEGREE OF INFLUENCE OVER OTHERS  ? = Unknown 1 = Low 2 = Moderate 3 = High
<b>Women</b>	Wash All Clothing (In Household and/or Via Piece Jobs)	+	3	3
<b>Clothing Owners</b>	Depend on Household Washers or Services of Piece Job Washers  Care About Quality of Washing Process	-	2	1
<b>IDIN</b>	Provide Project Support  Has Interest in Project Continuity	+	2	3
<b>Project Team</b>	Co-Create Solution	+	3	3
<b>Potential Investors &amp; Sponsors</b>	Provide Support and Aid for Scaling Product/Business	+	2	2
<b>Local Community</b>	Provide Ideas and Feedback	=	2	2
<b>Local Innovators &amp; Investors</b>	Provide Support and Aid for Scaling Product/Business  Leverage Solution for Other Efforts and Businesses	=	1	1
<b>Complementary Services &amp; Businesses</b>	Leverage Solution for Other Efforts and Businesses	+	2	2
<b>Agents of Sustainability</b>	Support Fabrication and Maintenance	+	3	2

## USERS

### **Primary User = Household Clothes Washer**

Our primary user is a woman (or girl) who washes clothes and linens for their immediate and/or extended family. She walks a kilometer each way to fetch 10 liters of water from the community stand pipe. Once she returns to her plot/home, she sets up her washing area near the clothing line (typically in the partial-shade just outside her primary dwelling). She pours all her water into 3 medium-large oval tubs. She adds a large amount of clothing detergent to the first tub, a small amount of clothing detergent to the second tub, and a large amount of clothing softener to the third tub. She also has an extra empty tub or bucket nearby to temporarily hold clean items and carry clothes/linens to the clothing line. Her process for washing varies somewhat by the type and dirtiness of the clothing/linens, but in general she washes the whites and cleanest clothes first and thoroughly wrings out each item between tubs to conserve water. She scrubs most items by hand by bunching the fabric into her fists and leveraging the strength of the heels of her hands. She may use her feet and body weight to scrub the largest or dirtiest items. She uses the same water for all the clothes/linens. Once clothes are clean and wrung out, she hangs them on the clothing line to dry (turning most items inside out to protect them from fading and airborne dust). Clothing dries rapidly in the desert sun and breeze, but some heavier items and linens may need to hang for a couple days before drying completely.



### **Secondary User = Piece Job Clothes Washer**

Our secondary user is a woman who washes clothes and linens for other community members as a piece job. She walks with her children to her customer's plot/home. Her customer, typically a single man, provides all the supplies she needs to wash his clothing and linens (water, tubs/buckets, detergent, and clothing line). She follows the same general process as our primary user, but she is particularly conscious about the quality of her work and the cleanliness of the clothes/linens so that she can keep her customer happy and support her family.

## DESIGN PROCESS

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### SUMMARY

Our team followed the IDDS Design Spiral process. There were three phases, each generally a week in duration: Framing the Problem; Creating a Solution; and Developing a Prototype Product. We went through three iterative stages within each of those phases: Information & Insights; Ideas & Approaches; and Implementation & Validation.

### USER RESEARCH

We consistently incorporated feedback from our local team members (most notably Tabaxlae) and, at key moments during the design process, were also able to seek and incorporate feedback from other IDDS participants and other user/community stakeholders. During the Framing the Problem phase: we hosted an information gathering session in the form of a tea party (with 14 local community members – 13 women and 1 man); we observed and helped a couple local families wash their clothes; and we each washed our own clothing using the local methodology and supplies. We also gave presentations and hosted show-n-tells for the local community during the Creating a Solution and Developing a Prototype Product phases.

Our team synthesized the following information from our various information gathering efforts.

#### Challenges

- water scarcity – machine should use less water than hand washing
- machine should wash clothes as clean or cleaner than hand washing
- wet wool blankets are heavy and hard to wring
- machine should be easy to use by elderly users
- variable materials/size/dirtiness of clothes to be washed
- no clear way to measure cleanliness of clothing/linens
- economic and cultural challenges in creating a community laundromat

#### Opportunities

- people seem generally willing to spend around P500 on a machine per household
- free water for the people of D'kar
- the attenders of the tea party session very willing to support our efforts
- the clinic and school may be in a position to spend more on a washing machine
- hot water has greater stain removing power
- reach of mobile devices due to the high number of piece workers
- people generally dispose water with very high concentration of soap/dirt after washing
- need for water recycling and purification
- washing powder and softener not viewed as a purchasing burden even though its expensive for them

- women seeming adamant on finding an easier and faster way to wash clothing/linens
- women of D'kar are the best agents of future sustainability

#### Gaps

- electric power not available in most households
- no water taps at most households (have to walk to community stand pipe)

#### Surprising Facts

- church pays for all water for the people of D'kar
- people dry their clothes inside out to prevent sun bleaching
- single men pay women (via piece jobs) to wash their clothes
- a few families have their own water tap and/or a way to collect/store water

Throughout the majority of the design process, our team focused on our primary user (the household clothes washer).

## USER NEEDS

During the course of our project, we validated that our primary (and secondary users) had the following prioritized needs:

1. Hand & Skin Injuries
2. Water Conservation
3. Cleanliness of Clothes/Linens
4. Solution Cost
5. Time & Effort of Manual Labor

## INITIAL CONCEPTS & EXPERIMENTATION

Our team came up with a large number of initial concepts, ranging from the incredibly simple to the more complex:

- commercial textured household rubber gloves
- textured household rubber gloves modified with washboard-ridges on the palms
- washboard (sized for locally-available buckets/tubs)
- a mesh bag for washing and/or wringing
- a hand-powered double-barreled washer/spinner (horizontal orientation for washing, vertical-orientation for spinning)
- a foot-powered side-loading washer/spinner
- a mechanized swiveling-accordion washer

We created sketch models for each of these concepts and demonstrated them to our stakeholders during our first community design review.

The simplest concepts didn't attract much attention, though users did agree that the gloves would protect their hands from the harsh detergent and that the washboard could aid

scrubbing. The majority of users (and other community members) were interested in the foot-powered side loading washer/spinner concept. Men were primarily fascinated by the power mechanism. Women appreciated the concept, but expressed concerns about the potential lack of modesty while pedaling (seeming to prefer moving the pedals with their hands) and the cleanliness of clothing.

## ADDITIONAL REQUIREMENTS

In addition to addressing the prioritized user needs listed above, our team identified the following additional requirements for the final prototype:

- Human-Powered
- Simple & Easy to Use
- Locally-Sourced Materials from D'kar, Ghanzi, or Maun (Fabrication & Maintenance)
- Low-Cost (Fabrication/Purchase & Maintenance)

## CONCEPT SELECTION

We used a pugh chart analysis to evaluate all of our concepts according to our list of prioritized user needs and additional requirements. One concept, the foot-powered side-loading washer/spinner, received the largest number of points by a decisive margin and was the inspiration for our final prototype. Unfortunately, we're unable to include more details on our concept evaluation since those pieces of documentation were lost.

## FINAL PROTOTYPE

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### SUMMARY

Our team selected the foot-powered side-loading washer/spinner concept as the basis for our final prototype. Its design was inspired by a front-loading Miele washing machine (renowned for its water efficiency and cleaning power). Like a Miele, our prototype has a horizontal orientation and is comprised of a perforated inner cylindrical drum with baffles rotating inside a stationary waterproof outer drum. Its washing mode needed to support three key movements: soaking, a bi-directional back-and-forth pendulum-like "wishy-washy" movement in the bottom half of the cylinder and a faster rotation "scoop-and-drop" movement in either side half of the cylinder leveraging gravity to scrub the clothes. For proper spinning, which maximizes water conservation and facilitates drying, the machine needed to spin rapidly in one direction to centrifugally force water out of the clothes from the inner drum to the outer drum where it could then be drained. Based on user feedback we received during and immediately after the first community design review, we knew from the outset we needed to find an alternate way to power the machine (either by hand or with more modesty-preserving foot/leg movements). We

also discovered that the bicycle parts used in our initial concept were not available within our required geographic boundary.

We created sketch models for a number of different power mechanisms, utilizing everything from gears to pendulums to flywheels. We were still debating which to choose when we discovered via internet research that there were a number of substantial difficulties related to stabilizing horizontally-oriented washing machines during high-speed spin modes (most notably dealing with unbalanced loads via an inner-drum suspension system and preventing oscillatory walking of the entire device – see Appendix B for reference documents). Given our limited time and requirements, our team decided to streamline our prototype and focus solely on the wash mode. Once the high-speed spin mode was eliminated, we quickly chose a hand-operated yo-yo inspired rope system to be our power mechanism.

In order to meet our water consciousness goal, we felt strongly that we needed some way for our users to remove water from their clothes during and after the cleaning process. So we brainstormed a variety of options, scored them against our user needs and additional requirements, and selected the highest scoring option (see Appendix C for documentation). When after extensive testing the “baggy squish” sketch model failed to adequately remove water from clothing/linens, we chose the next most promising next option the roller wringer.

## TOOLS & MATERIALS

Our washing machine and roller wringer were defined in large part by the scrap materials we found during the project. We salvaged an old large metal drum with holes in one of its end caps for the waterproof outer drum by removing that end cap and using that resulting opening as our washing machine’s door. The perforated inner drum was made from a flat piece of industrial metal shelving. We curved the metal to the proper diameter by running it repeatedly through a handmade contraption comprised of three metal rollers (in which the third roller was adjusted closer to the other two on each subsequent pass) then welded the two sides together. The inner drum’s three baffles were made from the same shelving material, but pressed into a v-shape by a piece of equipment in the workshop and riveted into place.



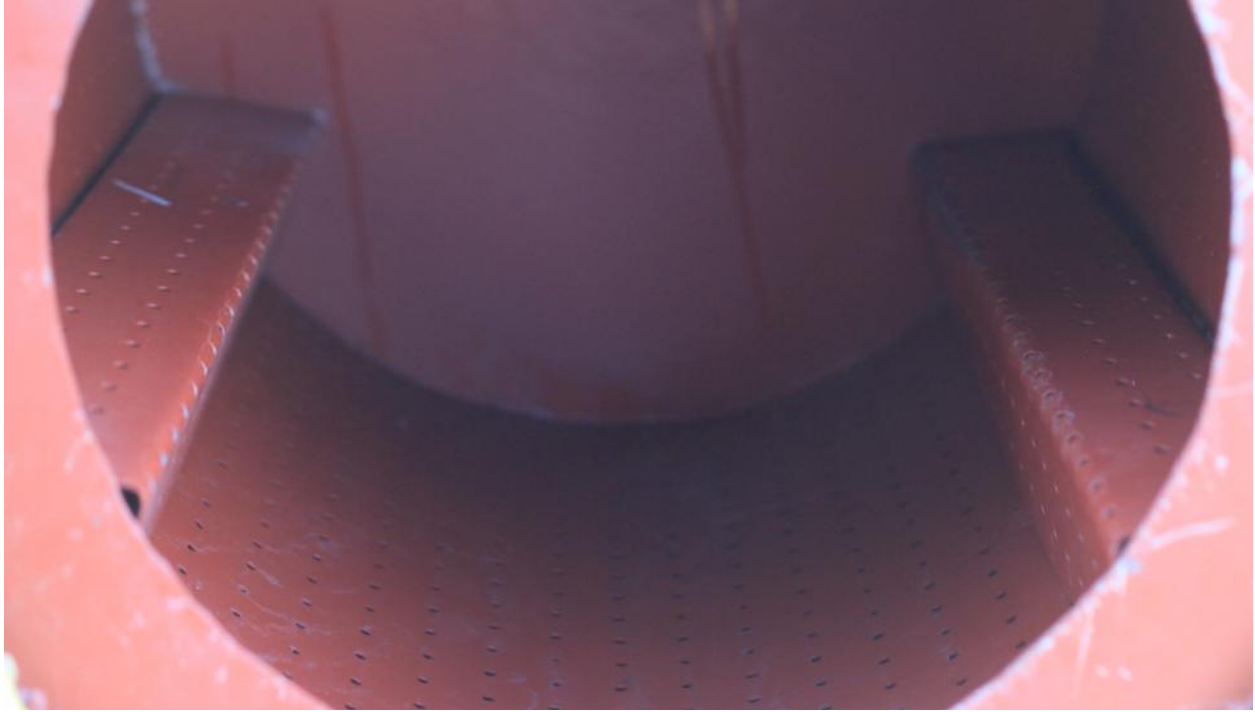


## HOW IT WORKS

### Stand & Cylindrical Drums

A stand, welded out of metal bars, supported the weight of the washing machine. When moved by the power mechanism, the perforated inner drum could be rotated inside the stationary waterproof outer drum. The circular wood and metal door on the outer drum was held in place by a hinge, latched closed by a handmade mechanism, and quasi-waterproofed by a foam seal.





### Loading & Unloading Clothing/Linens

Clothing/linens could be loaded and unloaded through the door in the side of the outer drum.







### **Adding & Removing Water**

Water (soapy, softened, or plain) could be added to the washing machine via a funnel put into the hole in the top of the outer drum. A valve on the bottom of the outer drum could be opened to drain water out of the machine. Its attached filter removed sand and other sediments from the drained water to aid in water reuse.





### **Power Mechanism**

A salvaged bicycle wheel with a diameter slightly smaller than that of the inner drum served as the heart of the washing machine's power mechanism. The wheel was wrapped a couple times by a rope. The two ends of the rope could be pulled from the same side or from opposing sides. When pulled back and forth, the rope rotated the wheel which then rotated the axel and inner drum to create the "wishy-washy" and "scoop-and-drop" movements.





**Roller Wringer**

When placed between two metal cylindrical rollers, clothing and linen could be wrung dry.



## PERFORMANCE & DESIGN REVIEW

We were able to test the basic function of the washing machine prototype, but not its effectiveness or performance in cleaning clothing/linens. We did not have time to test the basic function of the roller wringer.

During our final design review, we received the following feedback:

### **Overall**

- It was recommended that we add picture-based instructions to the washing machine to specify the amount of clothes, water, time, and process needed to clean clothes
- We discussed having a song to aid users in remembering the proper time/process for optimal cleaning

### **Stand & Cylindrical Drums**

- It was recommended that we use additional attachment points on the door since we would most likely get a better seal if we had 3 or 4 equidistant latches
- It was recommended that we investigate the use of silicon glue from an auto parts store to create our own custom-fitting gasket to better seal the door
- There were some questions about the availability and cost of reproducing our metal outer and inner drums

### **Loading & Unloading Clothing/Linens**

- There were some discussions about the pros/cons for waterproofing and maintenance of putting the door in the top of the horizontal cylinder instead of on the side (something we were unable to consider, despite our initial preference to do so, due to the state of our salvaged outer drum)

### **Adding & Removing Water**

- It was recommended that the pump mechanism be removed so that water could be added manually via the hole in the top of the machine, since complicated things like the pump were more likely to break during everyday use

### **Power Mechanism**

- We were complimented on our incredibly simple power mechanism – it was able to provide the three desired wash movements, but not over-engineered
- There was some concern about the wheel used in the prototype since bicycle parts were not available within our specified local region
- It was recommended that we investigate a convex wheel or covered pulley in place of the bicycle wheel, since there were some minor ergonomic related to the back and forth rope pulling and minor safety concerns about the possibility of people's fingers/hands being swept into the wheel

## NEXT STEPS

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### REFLECTION

Our team felt strongly that our project should continue. We agreed our solution and prototype had a lot of potential and, once functioning, could greatly improve the lives of women in D'kar. We were particularly thrilled to see the evolution of Tabaxlae's interest over the course of the project – by the end of the summit, she was incredibly passionate about our prototype and expressed strong interest in taking it home with her.

### CONTINUITY MODEL

We intend to continue evolving our project by supporting two of our local team members. Joseph Dii will become our project's lead. He'll join the local Innovation Center and our team pledges to donate 10% of any future washing machine profits back to the center. Before the end of the summit, Liz donated a small amount of interim funding (\$80 USD) to the team for purchasing materials needed for the next round(s) of refinements. Joseph Chipyoka and Liz drafted a list of future action items with Joseph Dii, and will continue to provide Joseph Dii and Tabaxlae with whatever remote support and guidance they might need. Our continuity plan below focuses on the remainder of the calendar year. We plan to reevaluate project status and next steps in early 2017.

### ACTION ITEMS

#### **Before End of Summit [Joseph Chipyoka & Liz]**

- Create Gmail Address & WhatsApp for Joseph Dii
- Teach Joseph Dii Email/WhatsApp Basics
- Joseph Dii & Tabaxlae Become Members of the Innovation Center
- Interim Funding

#### **Following 2 Weeks [Joseph Dii & Tabaxlae]**

- Establish Communication Between Joseph Dii & Joseph/Liz (1 Email Weekly or More As Needed)
- Run 1st Experiment on Prototype & Collect Performance Data
- Document Ideas for Future Prototype Refinements

#### **Following 3-6 Months [Joseph Dii & Tabaxlae]**

- Refine the Prototype (One Idea/Issue at a Time)
- Run Experiment on Refined Prototype & Collect Performance Data
- Document All Prototype Refinements & Experiments
- Communication Between Joseph Dii & Joseph/Liz (1 Email Weekly or More As Needed)
- *<Repeat 3 Steps Above Until Prototype Meets Functional Goals>*

## 2017

- Assess Project Status
- Determine Next Steps & Resource/Mentor/Partner Needs
- Replicate Prototype & Conduct Field Testing with Non-Team Users

## RISKS & CHALLENGES

- Prototype Doesn't Function
- May Need Additional People to Help Joseph Dii Complete Prototype
- Need Materials from Ghanzi (or Beyond) to Complete Prototype
- Need Money to Buy Materials
- Joseph Dii & Tabaxlae Have Other Life/Work Obligations
- "Ownership" of the Prototype's Technology
- Data Collection & Analysis
- Prototype, Even When Completed, May Not Clean Clothes Sufficiently
- Prototype, Even When Completed, May Use Too Much Water
- Prototype, Even When Completed, May Be Too Expensive to Replicate
- Communication Challenges Between Joseph Dii, Joseph Chipyoka, & Liz
- No Local Business Knowledge/Expertise

## FUNDING OBLIGATIONS

- Track All Money In & Out
- Account for All Expenses & Payments

## KEY METRICS FOR PROTOTYPE EXPERIMENTATION

- Time to Load Clothes
- Time to Insert Wash Water
- Amount of Wash Water
- Time of Wash Cycle
- Physical Effort of Wash Cycle
- Time to Remove Wash Water
- Efficacy of Wash Water Filtration
- Time/Effort to Unload & Wring Clothes (Between Wash & Rinse)
- Time to Insert Rinse Water
- Amount of Rinse Water
- Time of Rinse Cycle
- Physical Effort of Rinse Cycle
- Time to Remove Rinse Water
- Efficacy of Rinse Water Filtration



- Some Consistent Measure of Clothes Cleanliness
- Time to Unload Clothes
- Time of Wring Clothes
- Physical Effort of Wring Clothes
- User Experience Feedback
- Videos/Photos of Prototype & Its Use (Supervised & Unsupervised)

## ANTICIPATED NEEDS

None Currently

## CONTACT INFO

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### CONTINUITY CONTACTS

- Joseph Chipyoka (Zambia)
- **Joseph Dii (D'kar, Botswana)**
- Liz Hunt (United States)
- Tabaxlae Kaashe (D'kar, Botswana)

### FACILITATOR

- Carolina Menezes (Brazil)

### OTHER TEAM MEMBERS

- Frank Gaseitsiwe (Botswana)
- Sakhile Ndlovu (Botswana)
- Sixpence Sixpence (D'kar, Botswana)

## APPENDIX A

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### NARRATIVE USER PERSONAS

#### **Primary Persona = Qane**

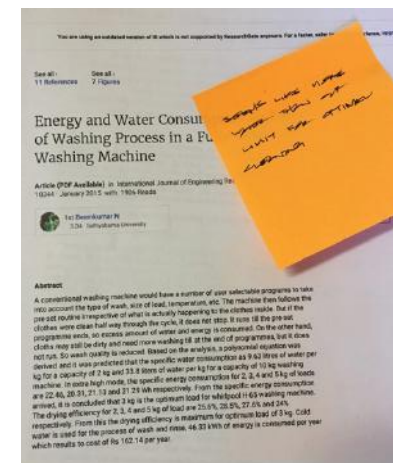
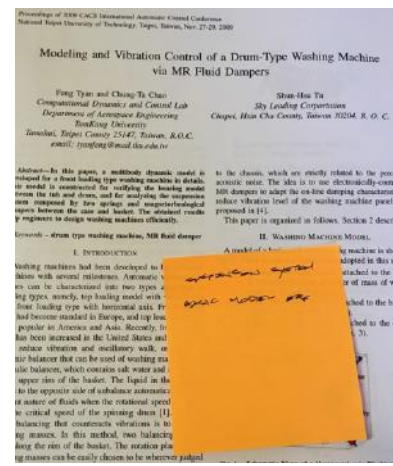
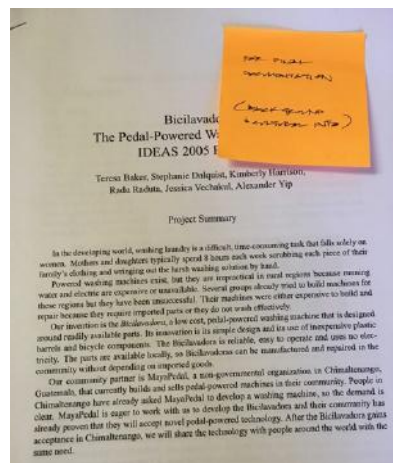
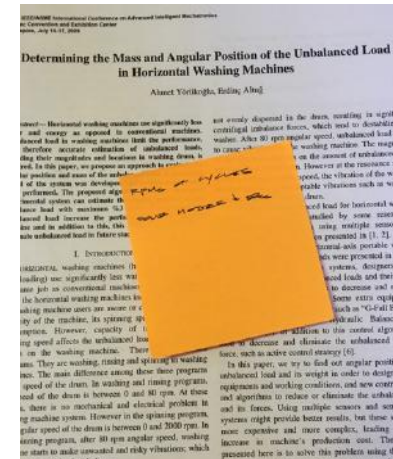
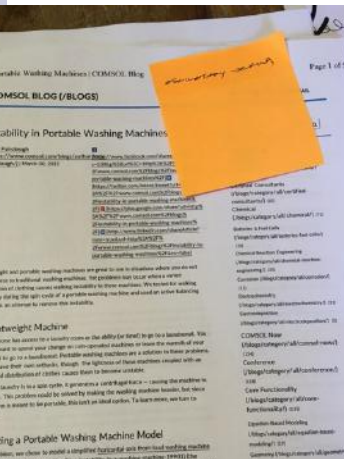
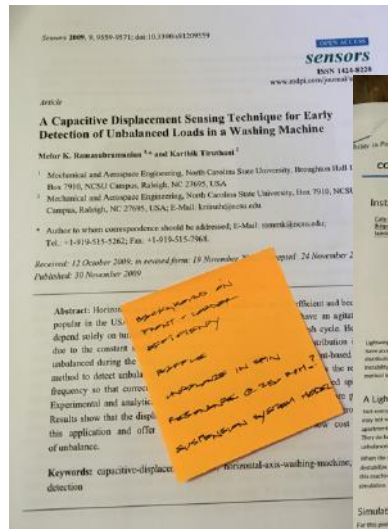
Qane is a 31 year old single woman with two kids between the ages of 2-7. She lives with her parents and four siblings in a yard with three traditional huts called rondavels. She's unemployed, but takes care of her family's home by doing almost all of the chores like cooking, cleaning, and washing. Her parents and grandparents financially support the family by working at the local privately-owned farm. Their home doesn't have a bore hole or stand pipe, so they fetch their water 1 km away at the local water tap. They heat their water and food on a fire. To wash her family's and boyfriend's clothes, Qane must fetch water and gather the dirty clothing and her washing supplies in the washing area outside near her hut. She fills two buckets with soapy water and a third with softener water and washes all the clothing by hand. Once clean, she wrings them out by hand and hangs them on the nearby line to dry in the sun and breeze. Qane is not satisfied with her life because she's always exhausted and stressed. Her parents are old and frequently ill so need to be taken care of. Their lives are financially insecure. She worries about her parents and her children. She'd love to make and sell beadwork, but doesn't have enough time or money to follow her dreams.

#### **Secondary Persona = Bau**

Bau is a 28 year old single woman with three kids between the ages of 3-10. Her parents passed away, so she lives on her own in a yard with one traditional hut called a rondavel. She supports herself and her kids by doing a variety of piece jobs in her community (like washing clothes and cleaning houses/yards). She also takes care of her family's home by doing all of the chores like cooking, cleaning, washing, and shopping. When one of her children gets sick, she's unable to do her piece job because she needs to stay home to take care of him/her. Their home doesn't have a bore hole or stand pipe, so they fetch their water 1 km away at the local water tap. She heats their water and food on a fire. When she does piece jobs, her customers provide whatever supplies (water, firewood, etc.) that might be necessary to do the work. To wash her customer's clothes, Bau brings her kids to the customer's home where all the supplies she'll need (like buckets, water, and soap) are provided for her. She fills two buckets with soapy water and a third with softener water, then carefully and thoroughly washes all the clothing by hand. Once clean, she wrings them out by hand and hangs them on the nearby line to dry in the sun and breeze. It's very important that she does high quality work to keep her customers happy. She services XX customers per day. Bau is not satisfied with her life because she's always exhausted and stressed. Her life is financially insecure, she always worries about feeding her children. She'd love to have a permanent job, but she doesn't have sufficient qualifications and her life and schedule are too unpredictable.

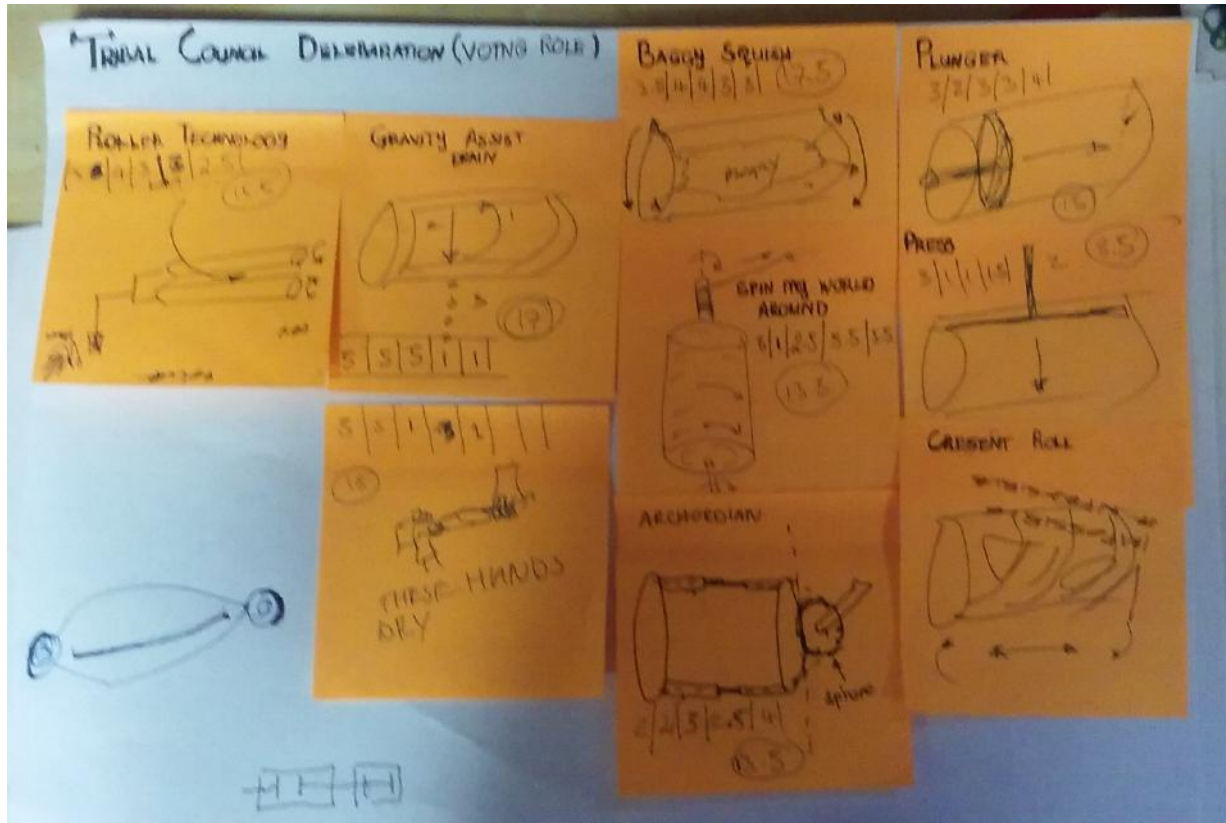
# APPENDIX B

## INTERNET RESEARCH ON UNBALANCED LOADS & OSCILLATORY WALKING



# APPENDIX C

## WATER REMOVAL IDEAS





# APPENDIX D

## FINAL PRESENTATION & POSTER





**EZ NCORO**  
HUMAN POWERED WASHING MACHINE







**Key Features**

- Human-Powered
- Built with Locally-Sourced Materials
- Low Cost (Purchase & Maintenance)
- Simple & Easy to Use
- Water Conscious

**Team**

- Frank Gaseitwe (Botswana)
- Joseph Chipiyoka (Zambia)
- Joseph Dli (D'Kar, Botswana)
- Liz Hunt (United States)
- Sakhile Ndlovu (Botswana)
- Sipence-Sipence (D'Kar, Botswana)
- Tabakae Kaashe (D'Kar, Botswana)
- Design Facilitator: Carolina Menezes (Brazil)

Washing clothes is a time-consuming and labour-intensive activity for the women of D'Kar. It often takes them a full day each week to clean their family's clothes. Water scarcity further complicates the process. In addition to the usual challenges of washing and rinsing clothes by hand, many women must walk a kilometre or more each way to fetch water from a community tap.

Our team created a simple, low-cost, human-powered washing machine and wringer to reduce the time and effort needed to wash clothes and conserve water in each step of the process. By using this product, the women of D'Kar can spend their extra time on other household chores, with their family, community, or generating income.