Huiku: IDDS Botswana 2016 Deep Sand Wheelchair Project

Project summary

At the 2016 Botswana International Development Design Summit, the designers aimed to develop an intervention which enables mobility solutions for wheelchair riders in multidimensional poverty and deep sand contexts. This report outlines the context, the design process, our suggested interventions, and opportunities for continuity. We hope these contributions will further the space towards developing safe, secure, and enabling mobility technologies to be furthered towards helping the global community move in difficult environments.

Context

Background

At the Botswana International Development Design Summit 2016, the project was suggested and decided upon to developing technological interventions towards solutions for people with disabilities dealing with endemic poverty. In areas of desert and deep sand, people with mobility impairments have critical issues with getting around. The issues of disability are complex and pile upon the already precarious context of poverty for the San community. However, currently there is a population of 50-60,000 people; they are a community who has experienced discrimination through their recent history. The United States Department of State described ongoing discrimination against Basarwa (San) people in Botswana in 2013 as a "principal human rights concern," particularly, the government's displacement from the San community from their historical land[1].

Many of the mobility technologies available are difficult to use in deep sand, and wheelchair riders may be dependent on family members or other caretakers to make sure they get around to places: church, school, or the clinic. If those people are not available then the people cannot move around. We aimed to develop technologies to help wheelchair riders move around more easily.

Community Description

By community report, approximately 2000 people live in D'Kar. For many of the community members, they engage in manual work, including subsistence farming, and cultural activities like the making of art materials, like bracelets, necklaces, and looking after livestock, including cows, goats, and chickens.

Important communities which help to support people who live in D'Kar include the Church Council, and the Kuru Development Trust. The Church council was sold the land of D'Kar some while ago, and they make most of the major resource allocation decisions around D'Kar. They allocate plots of land to particular members of the San community, and take care of the drinking water for use by the community members.

The Kuru Development Trust aims to develop sustainable livelihoods for the D'Kar community based in competent San leadership through education, community mobilisation and empowerment. The activities of the art project are highly dependent on tourism: Activities of the community include the Kuru Art Project, where ten to fifteen artists work in a variety of modern media to represent the San community, the Dqae Qare Game reserve, which offers a cultural experience to visitors for intergenerational learning among the San, and the Museum and Culture Centre where tourists can learn about the San culture and purchase crafts and art. The D'Kar Trust also supports the annual Kuru Dance festival, the largest cultural exchange for the San community[2].

Another critical community here in D'Kar are the Naro Language Translators. Originally from Holland, they have been in the area for twenty five years, working to develop language translation solutions for

[1] https://en.wikipedia.org/wiki/United_States_Department_of_State

[2] http://www.kuru.co.bw/Kuru_Dkar.html
https://www.culturalsurvival.org/publications/cultural-survival-quarterly/botswana/kuru-family-organizations

the San community. The main task of the team is to translate the Bible into Naro, and by corollary develop a written version of one of the San languages, Naro. While they have done this, they have developed language translation and dictation services for the San and other representatives, and have been a staple in the D'Kar religious and development community.

The climate of the community makes it very difficult to be mobile if you have a physical disability. Some people living with disabilities have received assistance from some organizations, such as wheelchairs from the Church of Latter Day Saints (LDS Charities), but the wheelchairs are very difficult to move through the sand. Moreover, the sand is tiring to walk through. People move by walking, or by car or by donkey, to get from place to place. Safety of mobility is a critical factor; vehicles often move quickly down narrow sand roads through D'Kar. We were not able to fully understand what assessment and provision of mobility products and services is available in D'Kar, and partnering with the clinics and regional hospitals, along with other health programs and Disabled Peoples Organizations (DPOs) will help us understand the community context moving forward.

Getting to the clinic is difficult through deep sand, and there are limited government services which help people living with disabilities in D'Kar, such as accommodating schools for disabled people, or physical therapists and occupational therapists which would help them with their needs. Many times, people in the area are treated to address the symptom instead of the problem.

It is difficult to move from places to get materials necessary to survive; the closest town, Ghanzi, is approximately thirty minutes away by driving. For those who have further difficulty moving over distances, accessing resources they need to exercise freedoms to live whole lives, including substantive, educational, political, economic, or others, is even more difficult.

Key stakeholders and typical users

Our primary stakeholder and typical users are active wheelchair riders whose physical impairments prevent them from walking but are still strong and capable of pushing themselves on a standard push-rim wheelchair safely. The target users are those who already own wheelchairs but live in sandy environments, similar to D'Kar, where it is difficult for wheelchairs them to maneuver without much effort. We built our prototype to fit a standard hospital wheelchair frame, but future prototypes could be made adaptable to other types of common frames in order to address the needs of a wider user base. Our deep sand mobility-enhancing accessories are designed for those who have the desire to be more independent with their current wheelchairs, both around their house and in the larger community. Note that we did not set out to build a new wheelchair; instead we have worked on technology to retrofit existing wheelchairs to work better in deep sand environments.

Another set of stakeholders is the family members and the care providers who regularly help those with disabilities get around in their wheelchairs. These helpers, specifically those that we have come across, are usually children and women who have to juggle many other responsibilities besides taking care of the wheelchair riders. For D'Kar, this set of user also includes the ambulance drivers and the nurses at the clinic, who often transport people with disabilities from their homes to the village clinic or to the hospital. We developed this prototype with these users in mind, hoping to save them time as well as effort.

Disabled People's Organizations and disability advocacy groups are other stakeholders that we have not

connected with thus far, but would like to as the project moves forward. Another set of stakeholders are local and national service providers and health care workers working with people with disabilities. We hope these groups can both guide the project direction and provide needed input about process and technical decisions.

Other stakeholders in the local community are the mechanics and the bicycle parts suppliers. Though not users, they are essential in the maintenance of the products. We used bicycle parts and simple fabrication methods for our prototype with the hope that anyone with basic mechanic training can diagnose and fix problems when they arise. Thinking on a more global term, the final set of key stakeholders is the medical service provider and the wheelchair development community all over the world who can provide valuable feedback and assist us with future testing and development of this prototype.

PATH Statement

Active wheelchair riders in D'Kar have difficulty moving through the sand and gravel terrain, which limits their mobility and their interactions in the community. They often have to exert a lot of effort to move independently, or rely on others' help to move around and beyond the house. We have developed accessories, including wider, more durable wheels and levers to drive those wheels, which are designed to be adapted to existing wheelchair frames so that the riders can retain the comfort of their seating support while being able to move through sand more easily. We hope this would promote better access to resources and opportunities that will better integrate people with disabilities to their community.

Design process

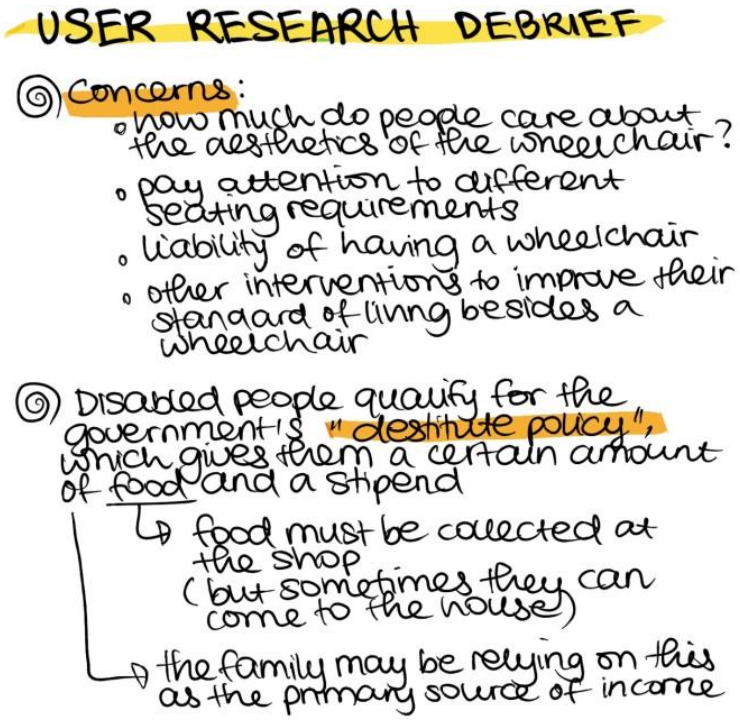
Summary of design process

Design process is the way of finding the solution to the problem the community is facing, so design is about solving a problem or getting a problem to solution by the creation of a technology. The wheelchair in deep sand is a problem to people with mobility issues in D'Kar community. Therefore, the following stages were found to be helpful for the wheelchair group to go through in solving and creating a valuable solution in developing a deep sand wheelchair. By gathering information, the group went through the D'Kar community to collect data on critical information about the community members' lives:

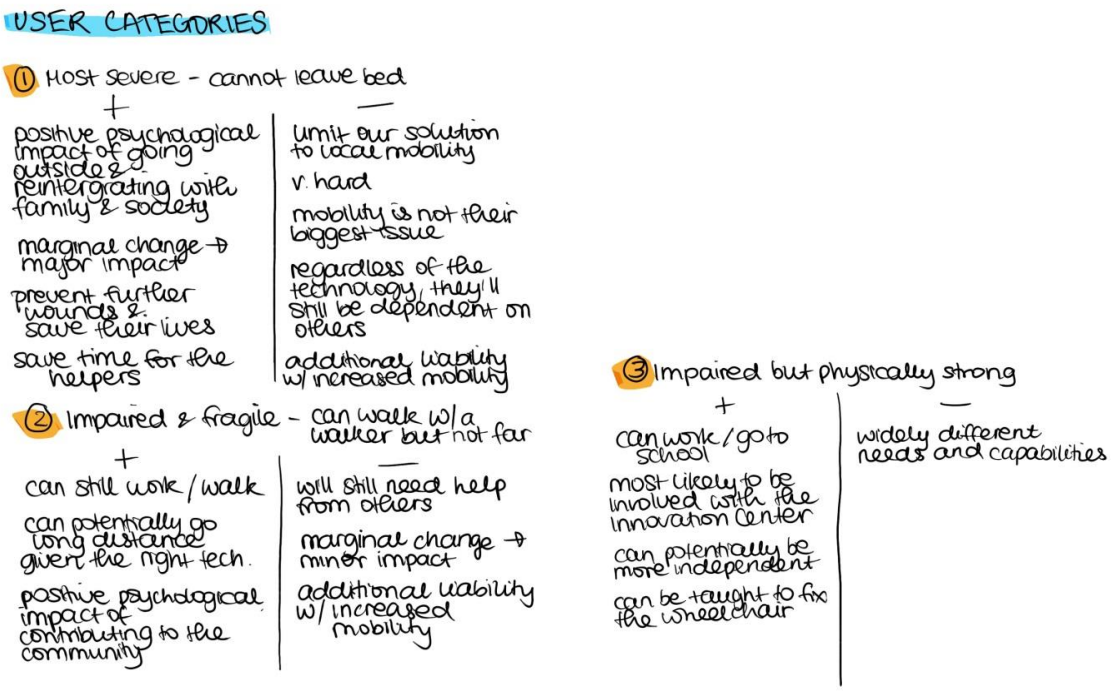
- how they live,
- what a normal day is like,
- who they communicate with and depend on,
- how they became disabled,
- how it has impacted their lives,
- if they can work or go to school,
- what places they would like to go.
- What their living environment is like,
- What amenities are offered to them because they are disabled,

and whatever other pressing information came to mind during the interviews. We had time for seven separate initial interviews, where we found three different types of user communities, which are summarized here out of respect for privacy.

User notes from information gathering was depicted below.



With this initial information, we realized there were many issues that the community members had to deal with besides mobility: lack of access to clinics, to money, to healthy food and water. Moreover, the issues of people who are disabled were very difficult to compartmentalize. However, as we have a short amount of time, we had to choose a specific type of community to focus on. By developing three separate personas of people who are disabled, we compared the pros and cons of choosing different user groups. With this information, we also considered if we were to address other problems unrelated to mobility, that we might not have the knowledge, the skills, or the resource capacity to address other important issues of the disabled community. With these considerations, we decided to focus our efforts upon addressing mobility issues of impaired but physically strong community members; particularly, people that could move around independently. One pressing concern is the reality that in the D'Kar context, we only had one user which represented this user group; a high school student named Jephta, listed in the user profile. It meant in the future, a decision had to be made about whether to design specifically for Jephta, to make his life easier, or to aim to design for active wheelchair riders (like Jephta) towards the aim of wider replicability and manufacturability of the project design. The data from the meeting is displayed below.



We also had the opportunity to frame and reframe the problem towards one which would address something the community truly needed, and one that could be worked towards during our short stay in D'Kar. Moreover, we were also influenced by a saying of our design facilitator: by focusing upon helping people, then those people can then help others by paying it forward. Thus, we then decided to focus upon mobility issues of those who were most likely to be able to use wheelchairs themselves, and could likely help others once they are helped. We decided to focus upon **decreasing the effort of independent mobility of wheelchair users outside and around their house**, and to adjacent houses around them (approximately the area from 10 m to 100 m of movement. The potential problem framing workshop we engaged in were collected and are depicted below.

With this issue, we then aimed to think of as many ideas as possible. We engaged in blue-sky brainstorming activities, and did model sketching and prototyping to try and see which ideas would make the most sense when developing mobility solutions for independent wheelchair riders. We also engaged in sketch modeling, and rapid prototyping, to develop an understanding of which ideas would work, and which ideas would make sense to modify and adapt to this context. Some of those examples include the Monster Wheelchair design, where we developed a mock wheelchair from car tires, and sketch models of wire wheelchairs, tire treads, and bike pedaling materials which add a mechanical advantage to the moving process. The development of those activities is depicted below.

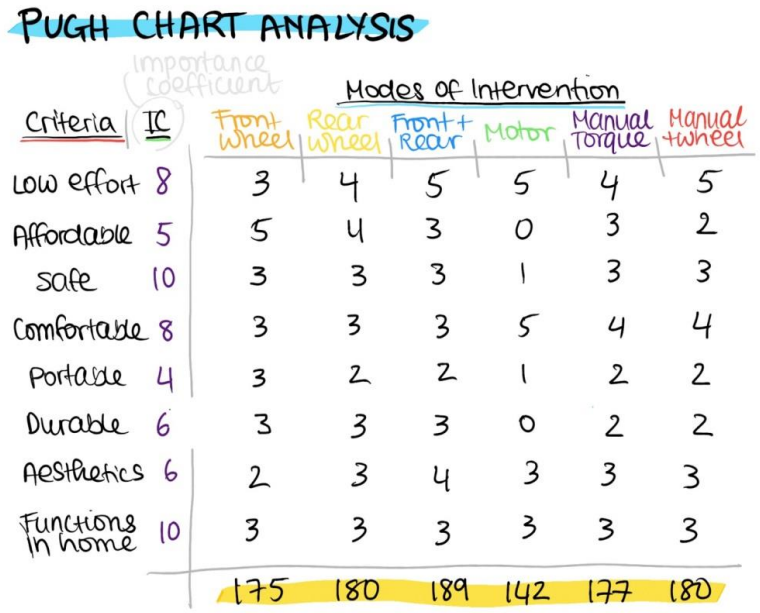
We prepared the sketch models for the opening of the community innovation center, where an interim design review was held. We used the crowds to collect data on which designs were worth furthering, and which ideas should be scrapped towards our goals. To make sure we answered the questions we needed to, we wrote categories of questions for which we needed more information. Those questions, and pictures of the design summit, are depicted below.

After the community design review, we learned more about people's perceptions of the designs and more about user needs. The monster wheelchair design might have a larger surface area on the sand, which would increase flotation, but the current use of large wheels was too heavy to move and the aesthetics did not appeal to Jephta and other young wheelchair users. The tank –tread design might move easier across the sand, but it was technically difficult to build, and would be even harder to manufacture in a local environment. Thus, with our further information about which design would, and would not work, we decided to brainstorm different, more specific wheelchair designs that make sense to try in the D'Kar context. With this information, we grouped different wheelchair modification to different categories wheelchair designs; we used this material to develop our categories for choosing our concept to develop as our final design. The results of those materials are displayed below.

Concept Evaluation Matrix + Brief Description of each of the concepts

After we developed the categories for the different types of wheelchair systems we wanted to test, we then developed a collection of metrics by which we would decide which type of system we would develop as a wheelchair team. The metrics are displayed in the "user needs and design requirements" section.

Using these metrics, we then developed a Pugh chart and analyzed if the six separate systems we chose would be better designs to focus upon for our final concept. The six wheelchair systems included: focusing only on the front wheel, focusing only on the real wheel, focusing both on the front and rear wheel, integrating a motor design, including manual torque, or focusing on both a manual torque increase and optional wheel modifications. We first set how important the criteria is compared to each other on a scale from 1 to 10, and we then rated the wheelchair designs on their ability to deliver on that particular metric. For instance, for the 'affordable' metric, it was considered moderately important, yet the least important criteria, so it was rated a 5 out of 10 as the importance coefficient. We then stated that focusing only on the front wheel would be the most affordable, and making a motor-powered system would be the least affordable, so they received ratings of 5 and 0 respectively. We then ranked all the systems, multiplied the values by their importance coefficient, and added the scores together. The results are displayed below.



The final scores showed some interesting data: except for the motor configuration, most of the scores were very similar. We believe this was an indication of two things: for many of the variables, they were very difficult to rate without further information upon the metric, all of the solutions had strengths. After reality checking the scores, we organically developed a further classification of work we wanted to focus on: either focusing on the wheels only, or focusing on the wheel and some type of added torque modifier (like a lever). We then decided to do it all, and try to create a torque modifier, a front wheel modifier, and a back wheel modifier, all on one type of wheelchair. TO do so, we split up our large group into three teams, all of which focus upon one of those parts. The teams were as follows:

Ketelelo + John: Torque Modification

Keemenao + Haily: Rear Wheel Modification

Pierce + Coexae + Sthunya + Xgaiga: Front Wheel Modification

Analysis and experimentation

We did two different collections of tests: one to choose the caster wheel we would use in the prototype, and tests after the prototype was built to evaluate the performance. The first of tests were mainly held by the front wheel team, to choose the type of wheel we should choose for the front caster. We had two different options we wanted to choose from: a small plastic wheel, and a larger bike wheel, yet one that was smaller than the 24 inch rear wheelchair wheels. Our team members agreed that the small wheel was smaller, cost less, and was easier to obtain in communities like Ghanzi, but did not perform as well on the sand. However, the larger bike wheel cost more, and the parts would only be available in places far away from D'Kar, such as Maun and Gaborone for a slightly lower price, but the wheel performed much better and took less force to roll through the sand. Also, the team agreed that the bicycle wheel was a better aesthetic fit, because it would match the rest of the wheelchair wheels. That being said, for the purposes of a prototype that worked as well as possible, and looked as good as possible for the community, we decided to develop the larger bicycle wheel in front.

Testing also occurred after the final design was developed, which is available in the next section. Because there were three separate modification teams which contributed to a single design, we wanted to complete different tests which showed the impact, as well as possible, of the three interventions individually on the single chair's ability to be moved across sand. The results of the different critical tests are displayed below. The table shows an approximation of an attendant pulling a wheelchair, but not force for self-propulsion. These results should not be interpreted very closely nor taken to indicate effort for a rider to propel themselves with this prototype.

Test Setup: The chair was dragged from the front with a rope attached to each of the rear wheel axles. A spring scale was used to take readings. We averaged the readings from the test, instead of using the maximum force. The test was done in the same level test track, racked smooth between tests, and in the same direction each time. There was a slight incline in the direction we tested. The sand seemed to be average depth, but less deep than is commonly found in the roads where vehicles drive. This test setup is not accurate to either a rider pushing themselves, or someone pushing a rider by the backrest canes, but it is more useful in comparison to the forces from someone pushing or pulling on the backrest canes. As riders propel themselves through sand, a force is exerted on the backrest that lightens the front end of the wheelchair, thereby helping lift the casters out of the sand and reducing the effect of casters plowing into the sand that we see from pushing on the backrest canes and pulling on the rear axles, as in this test.

Wheelchair/accessories or changes	**Force in Pounds**
Normal rear wheel + original front casters	68
Tilted back onto normal rear wheels	35
Tilted back onto prototype fat rear wheels	20
Prototype fat rear wheels + original front casters	80 *we are not sure why this force is higher than that of the normal rear wheels + original front casters
Normal rear wheels + prototype extended caster	43
Prototype fat rear wheels + prototype extended caster	35

The unmodified wheelchair was pulled through the sand with a force of 68 lbs. In practice, riders being assisted by another person will likely be moved in a wheelie position through deep sand, which requires a force of 35 lbs.

The modified (front and rear wheels) wheelchair was pulled through the sand with a force of 35 lbs, and when tilted back onto the modified rear wheels, required a force of 20 pounds. Thus, the rear wheels can reduce the force required by an attendant from 35 to 25 lbs, or allow the attendant to exert the same 35 pound force without requiring a wheelie, which may be safer and more comfortable for rider and attendant.

When we added the fat tires and extended front caster wheels to the wheelchair, the force to pull the wheelchair from the axles was 80 pounds (we don't know why this is higher than the force for the un-modified wheelchair, but it may be related to the front casters "digging" in deeper into the sand when there is increased rear wheel floatation).Then we tested the normal wheelchair rear wheels with the added extended front caster wheel, which required 43 pounds to pull. Then we moved to the final prototype by with extended front wheel and fat tyres which required 35 pounds to pull.

For testing the lever force, the caster was held facing forward and force was applied to one lever from outside of the wheelchair. This test was ***not*** *representative of the forces acting on the wheelchair when levers are used by the riders, because there is no backward force put on the backrest (and thus lightening the front wheels, as happens with rider use of the levers. The test with the original front casters was not conclusive because the rear wheel spun in the sand without propelling the wheelchair (we think this is due to the way the test puts forces on the lever but not the backrest, as a rider would do. We did not have a way to measure pushing/compressive force at the time of this test.)*

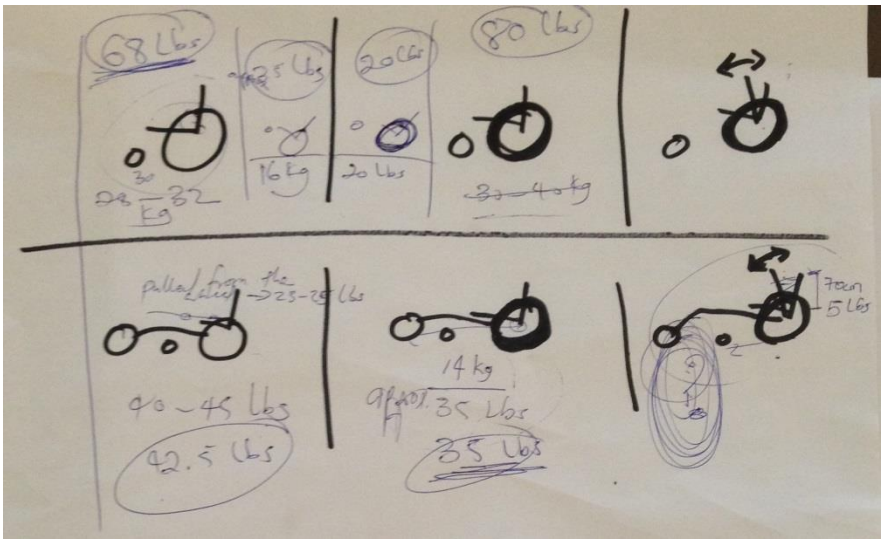
Lever test with prototype rear wheels + prototype extended caster	5 Pounds force @70 cm from axle.
Lever test with prototype rear wheels + original front casters	NA

Photos showing some of the testing setups

For the future, more in-depth testing is required to find the impact of the wheels on sand when compared to a normal wheelchair. A few tests we suggest include:

- Force tests (push & pull tests to see weight of the chair when moving, for all configurations including forces measured from the riders position),
    - Force to start moving
    - Maximum force needed
    - Average force needed
    - Force while imitating independent rider
    - Force while imitating being pushed/pulled)
- Speed tests (from one place to another)
    - Speed independent
    - Speed with pusher/puller
- Fatigue tests (how far/how much time one can ride until you get tired)
    - Fatigue independent
    - Fatigue with pusher/puller
- Stress tests (to see strength, stress, failure modes)
- Too much sand test (how much sand is too much for moving with wheelchair?)
- Getting onto ledge (up a curb or step) test
- Getting into doors (what's difficult? What should be changed? Which configurations work well?
- Imitated drought/imitated flash food

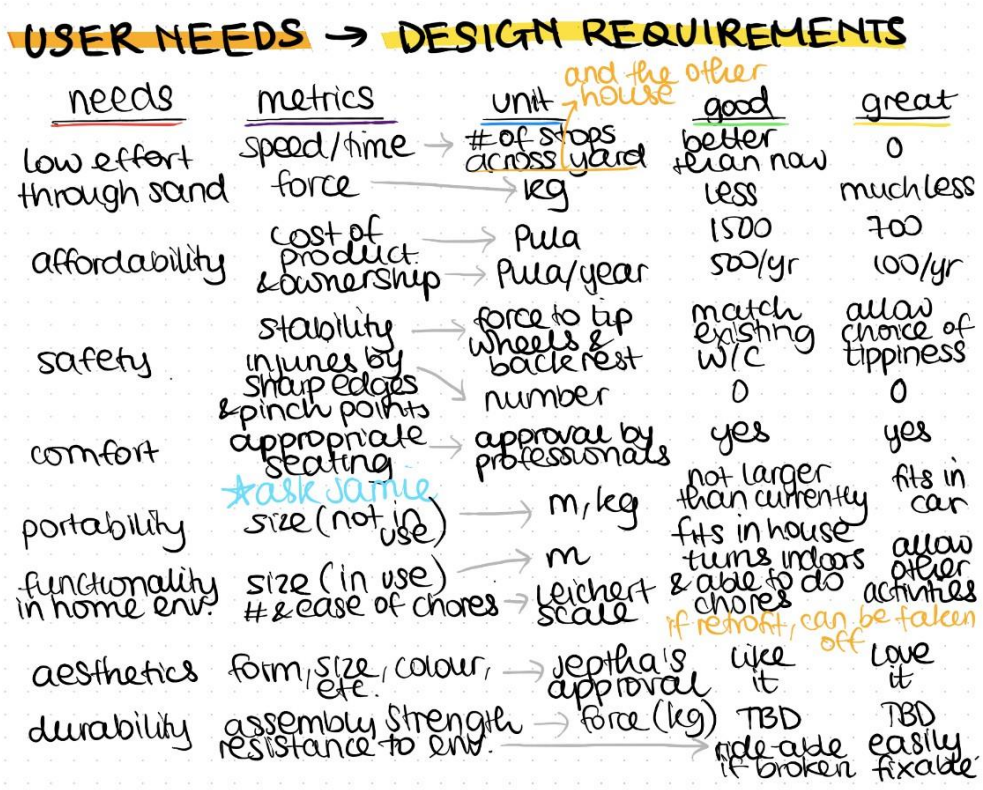
Force test results as recorded below for the record. Note that we used a scale that measured in pounds for forces up to 50 pounds, and a scale measuring kilograms for higher forces.



Technology/final prototype

User needs and design requirements

A list of the user needs, the design requirements, and how we translated them into metrics are described below.



How it works (optional, but useful: sketches or CAD drawings

Our prototype replaced parts of the user's existing wheelchair simply and affordably, with minimal changes to the seating (Seat, backrest, footrests). The wheel modification seeks to increase flotation, or decrease pressure of the wheels on the sand it rolls over. The user's existing rear wheels can be replaced with a double-rimmed rear wheels assembly. This increases the width of the tire, therefore increasing the contact patch and reducing the load per area of the tyre of the user moving on deep sand. The front wheels are moved further ahead of the caster wheels, and angle the chair such that the original casters are above the rolling surface by 5 cm to keep them from dragging. Because the distance from the wheelchair center of mass to the front caster is increased, it exerts less force on the sand than the original casters and thus rolls easier than the original wheels (even though 2 casters are replaced with 1; the larger diameter increases the length of the tire contact patch as well). Pictures of the front and back wheels are displayed below.

Performance

For the full results of this testing, refer to the section "Analysis and experimentation" earlier in this report.

The performance of the wheelchair was tested with Sethunya Leburu, who has a weight of 141 pounds.. The performance was measured by performing two types of test using the same wheelchair. In the first test, the normal rear wheels and the castor wheels were used. Using a spring scale, the force required to pull the chair through the sand was measured as 68 pounds.

In the second test, the normal rear wheels were replaced with our double-rimmed rear wheel assembly and a front tyre of large diameter was added in front of the castor wheels. Using the spring scale the force required to pull the chair through the sand was measured as 35 pounds. Although the tests are rough approximations, this shows approximately the effort, in pounds, to move the wheelchair forward is halved (in a test similar to an attendant pushing a rider). If the wheelchair is tilted back on the rear wheels, the forces are 35 pounds for the original skinny tires, and 20 pounds for the double-wide tires. This is the method our team observed Jephta using to travel longer distances with family members.

Tools and materials required

The tools required to design and make the wheels are displayed below:

- Power tools
    - Welding machine
    - Angle grinder (large for cuts, small for polishing/cutting)
    - Handheld drills
    - Drill press
- Hand tools
    - Hammer
    - screwdrivers
    - wrench
    - spoke spanner
    - socket set
- Material
    - The user's original wheelchair
- Rear wheels
    - 24'' rims
    - 24 x 2.215 permatubes
    - 24 x 2.215 tyres
    - single-speed cassette
    - 6001 bearings
    - 12mm bolts and nuts (M12 bolt, partially threaded, class 8.8)
- Front wheel
    - 20'' wheel (rim,hub, spokes)
    - 20 x 2.215 permatube (or pneumatic tube)
    - 20 x 2.215 tyre
    - Fork and its frame (38mm Square tube , flat steel bar)
    - Wheelchair hub (as caster swivel)

Lessons learned

Community engagement

We learned many skills during community consultations, such as expectation management and disability related issues. We learned how to manage the expectations of the community from the beginning of the project when we did community consultations. We made sure we did not promise PWDs we will give them wheelchairs by the end of the IDDS but rather we wanted their contribution in the development of a deep sand wheelchair. We also learned issues affecting PWDs in D'kar like lack of home-based care.

User feedback

After completing this concept, we collected this user feedback on our design.

We only had one user during our short testing because there was only one active wheelchair rider we knew and had a rapport with. Our user said they liked our prototype overall because it was able to move on sand with less effort. However the user said they did not like our lever system because it made him slower and he preferred using push-rims. The user also said the levers were too close to the body, which made them uncomfortable to use. We also realized, although it was a necessary design requirement for the wheelchair to be used indoors, that the wheelchair could not fit through normal sized doors in their house. We were unable to do further testing with the user on an extended period of time because we were concerned about making sure the tests were safe and ethical; and with the lack of a wheelchair service provider who could work with Jephta and other riders in D'kar to support prototype testing and evaluation, we limited our user testing until we can establish project partnership with service providers.

Troubleshooting

There were lot design tradeoffs that we made during the design process. We used fat tires instead of normal wheelchair tires because it helped with flotation. However the problem with the fat tires were that the wheelchair could not fit through a standard door used in D'kar. We decided to use the lever system because it helped with mechanical advantage therefore less effort was used for the user to push themselves; however, the levers cannot move as far per movement stroke as using the normal pushrims. We decided to use the front wheel because it reduced the pressure on the front caster wheels hence distributing the pressure on the wheelchair and making it easy to move through sand. However the front wheel made it difficult to maneuver in a limited space. Moreover, the front wheel assembly raised the front wheels off the ground, which kept the wheels from dragging on the ground, but it also meant it was easier to tip over for a given wheelchair setup. To take care of this problem in the meantime, we added an anti-tip bar on the back of the wheelchair for safety.

Next steps/project future

Reflection on project viability and other design opportunities

The current project, as it is, has two different levels of viability dependent on scale of development: viability in D'Kar, and viability outside of D'Kar. Based upon multiple discussions with wheelchair specialists, community members, and team partners, we feel it is difficult to make a case for developing a cogent plan for developing the wheelchair proof of concept in D'Kar.

A few reasons came to the group:

The complex context of D'Kar – one where a history of development intervention benefits were distributed to one group of people and not others. In this context, it seemed highly unethical to give a wheelchair to Jephta when other members of the D'Kar community couldn't receive one. (We also did not develop a product that is ready for use or long term user testing during the summit.)

The lack of a wheelchair service provider. We want to work with wheelchair riders to further the technology; however, we do not have the resources to implement such a program currently. As such, we would want to look for partners, like service providers, to test our products with rider according to current global best practices. As of yet, we don't have contact with service providers, and do not have resources to find potential service providers in the area close to D'Kar.

The lack of user groups which would be effectively assisted by the furthering of a project in D'Kar – As we stated before, only one main user was found which could feasibly use our product. We visited seven people with various disabilities, with many different issues they were dealing with other than mobility. This means the user groups, and thus the market for such a wheelchair, is decidedly low in the D'Kar context.

Moreover, all of the group members are unavailable to further the project in D'Kar - The group members either do not live in D'kar, have expressed disinterest in continuing the project, or are involved in too many projects in D'Kar to commit to the project to extend the technology further. One group member may be able to visit D'Kar on a few occasions to establish next steps for the project but we don't anticipate this being feasible for continuous project work.

Wrapping up our relationship with Jephta

As we stated earlier in the report, we decided as a group to continue focusing upon mobility solutions for independent riders, and Jephta was the main user which fit that description. As a result, much of our main user tests required us actively communicating and integrating with him as a member, so we decided to make sure that Jeptha was offered the appropriate recompense. However, we had to make sure that the ways we would follow up with him were innovations which would not require further mechanical innovation, the partnership with a service provider, or the development of further D'Kar partnerships that are a potential safety, durability, or continuity hazard. These are some things to discuss as possibilities moving forward:

Wheelchair repair and modifications

At his reporting, Jeptha received is wheelchair at 2012 - At the request of the wheelchair experts, we have visited Jeptha one more time and will repair parts of his chair to make sure it is working effectively and is ergonomically optimal. First, Jamie has checked Jephta's pressure-relief cushion to help keep the pressure low on his seating surface. We have also offered to replace his caster wheels, which are in poor condition, with new caster wheels which will perform better.

New Wheelchair to try for 6 months

One possibility we discussed was offering Jephta a wheelchair of the same model but with wide rear wheels, for him to try for six months. As wide wheels are an subsystem we developed for our innovation that are easy to put onto his current wheelchair model, and this modification will operate as an extended user test that will be followed up by Matt and hit MIT wheelchair course when they visit in January 2017.

Housing accommodations

We could also suggest changes to his house to make them more accessible to Jephta. We can make the suggestions to make ramps which lead up to his step in his house, either made of wood, dirt, or cement. However, such housing modifications would require a conversation between the whole family and Jephta, and imposing a design solution improper to their needs would be unethical. So, instead, Aaron and Jamie made a ramp up to the innovation center to increase the accessibility of the innovation center and show options for home modifications that might be interesting to Jephta and his family.

D'Kar Clinic

A nurse, which visited during the community feedback review and the final design review, was very interested in the final prototype chair we developed for deep sand. Her stated interest was one where she said the chair would be very helpful to move back and forth through sand, while getting patients through the deep sand to the clinic (or vehicles). The development, or addition of this wheelchair through deep sand, would require further stress and loading testing than we as a team currently have the capacity for, to make sure the wheelchair is safe, durable, and effective. Moreover, we do not have the human resources to develop a conversation with the nurse from the clinic to consider her interest in our prototype; because the chair requires more work before we as a design team are confident in its applicability as a product, she would have to take a critical role as a partner in that conversation.

Based upon all these considerations, for now, we do not have a plan to continue the wheelchair development in D'Kar unless other situations change.

Continuity/dissemination model

For this project to move forward and for the development of future prototypes, we hope to partner with these sets of stakeholders: active wheelchair riders who face similar challenges (with their service providers), wheelchair service providers working in the region, wheelchair manufacturers in southern Africa, academic institutions that are interested in incorporating this project into a course, and the International Development Innovation Network.

Different members of the team are interested in different stages of product development so they will be responsible for the relevant partnerships pertaining to their continued involvement in the process. The organizations listed below are potential partners and more direct contact information of specific people can be obtained through Matt, Jamie Noon (a facilitator on another project), or Aaron (whose contact information are in the team directory).

For the first phase of prototype development, our team would like to build relationships for design and technology development with partnerships between project and IDIN members in Botswana and Zambia (Disacare), and to work closely with partners in academic institutions, specifically MIT and UC Berkley, which will also focus on developing the technology and the business model for the deepsand wheelchair. We would like to continue working with some faculty members at the Department of Industrial Design at the University of Botswana as mentors for our team members who will continue working on the prototype in Gaborone.

For the second phase of product development, we would like to work closely with established wheelchair manufacturers in southern Africa. One team member will be working closely with Disacare in Zambia, but we would like to keep our partnership opportunities open to other manufacturers in the region.

Throughout the development stages, we need to work closely with service providers in order to have a proper relationship with wheelchair riders when gathering their feedback or performing user testing. Additionally, the team members who go on to develop the prototype can benefit a lot from receiving more in-depth training on wheelchair technology and care provision. There are a few rehabilitation centers and training programs in the region that can provide the training and the connection to wheelchair riders.

Further partners who could help with the extension of the project are also included below:

Western Cape Rehabilitation Center

Elsje Scheffler offers trainings.

ShonaQuip

This is a wheelchair program based in Cape Town, South Africa, that design facilitator Matt McCambridge used to work at. They provide a variety of assistive technologies and do service around the region. They do service, training, and have their own products.

Tanzania Training Centre for Orthopaedic Technologists (TATCOT)

Wheelchair technology training center in Tanzania.

PAWA, Pan African Wheelchair Congress

Reportedly, the 2007 report summarizes a series of remarks, panel discussions, and other conference sessions on how to promote appropriate wheelchair services across the African continent. The report also presents a list of resolutions made on the last day of the Congress.

The Church of Jesus Christ of Latter-Day Saints philanthropies

LDS charities distribute many wheelchairs globally to support the 20 million disabled people who need better mobility solutions. Reportedly last year, Humanitarian Services provided wheelchairs to 57,000 people in 54 countries. They included 430 wheelchairs to Kazakhstan, 1,484 wheelchairs to Vietnam, and 330 wheelchairs to Madagascar. They also offer trainings to wheelchair providers before the chair are provided.

CE Mobility

Established more than 65 years ago, CE Mobility is the largest wheelchair manufacturer and distributor in South Africa.

Kenny Mubuyaeta at Disacare in Lusaka, Zambia is also interested in the deep sand wheelchair project.

Ralf Hotchkiss is the founder of Whirlwind Wheelchair, and is interested in the design established here. Aaron worked with him for years, and he has worked around the world with wheelchair riders and builders, inventing and testing new products. Since 1979 Whirlwind has worked with wheelchair riders around the world to design durable and highly functional wheelchairs that perform well on rough terrain and are built in factories that contribute to local economic development.

Lastly, as we pursue this project further, we will require additional support from IDIN in the form of small funding to pay for training programs as well as connection to mentors and innovation centers.

Anticipated risks and challenges

Many actors involved, working towards similar, complimentary, or conflicting goals.

There are many different directions that the project could proceed in, and many different parties that are interested in progressing the project in different directions. This makes an opportunity for interesting opportunities for projects, but in many ways, different people might want different stakes in the project and its development, in its sense, a “turf war” of sorts. It is important that the members interested in involving themselves further with the project all know their personal interests, so that the boundaries of the future projects can be best understood and directed by the stakeholders.

Intellectual property.

The innovation we arrived at, which was a system of wheelchair accessories which were intended to work better on deep sand. However, each one of the innovations have been done before: wide wheels as prototyped by Ralf Hotchkiss and others, a modified single front wheel very similar to the FreeWheel wheelchair attachment, and the lever accessory, similar to many lever wheelchair products, including the Wijit, Rota, and the Leveraged Freedom Chair . The innovation in our project is the development of these

interventions for existing wheelchairs. Making sure that the innovators get the credit they deserve for the innovation, and that the project continues to move forward as an effective sand wheelchair accessory, must be a further consideration.

Anticipated needs for mentors and partners

We want to find ways to connect and stay connected in new opportunities, directions, challenges for the project partners. Because the project and community members will be connected in many different ways, and have many different visions for the projects, and we cannot control what everyone will be doing in the project, we can make sure that we stay in touch. This includes opportunities, concerns, networking opportunities, and many other issues. To address this issues, we have developed a Whatsapp page made for this issue that the group has agreed to address the group when news about the project to the rest of Huiku.

Finally, the largest problem is finding service providers who can advocate on behalf of, and work with, the wheelchair riders who will be part of this project moving forward. Wheelchair riders and people who are service providers can help make sure that the innovators, evaluators, business associates, and other stakeholders take into account the experience, health, and safety of the end user. Finding community members in the area that can partner with the testing of the current prototype is of utmost importance.

Contact information

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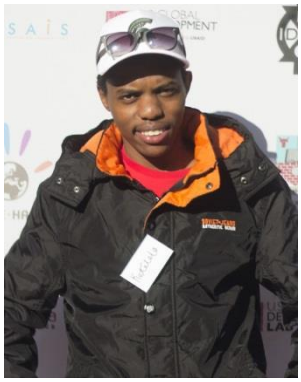

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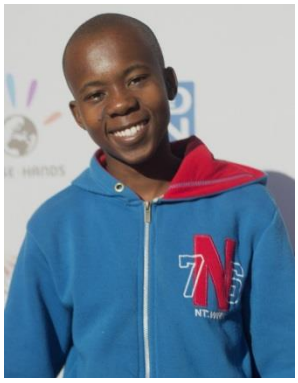

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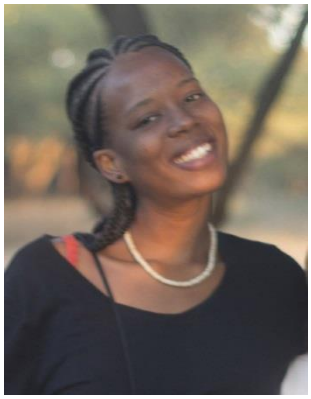

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Community partners

Wheelchair manufacturers:
CE Mobility, Johannesburg, South Africa
(www.cemobility.co.za)
Disacare, Lusaka, Zambia
(Kenny Mubuyaeta kennymubuyaeta@gmail.com)
ShonaQuip, Cape Town, South Africa (www.shonaquip.co.za)

Rehabilitation centers and training centers:
TATCOT, Tanzania
Western Cape Rehabilitation Center, South Africa
(www.westerncape.gov.za/facility/wester-cape-rehabilitation-center)
Church of Latter Day Saints training program, Maun, Botswana
(www.ldsphilanthropies.org/humanitarian-services/funds/wheelchair-distribution.html)

Academic institutions:
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UC Berkeley: Pierce Gordon
University of Botswana, Department of Industrial Design: OJ Sealetsa (sealetsa@mopipi.ub.bw)

IDIN mentors and funding opportunities:
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