Design and Introduction of Pit-Latrine Assistive Devices in Lira, Uganda

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***Abstract*—This project includes the planning, designing, and present implementation of a humanitarian engineering project named Simple Seat, Better Lives. The goal of this project is to address the problem concerning the use of pit latrines in Uganda, specifically Lira, by individuals who have been handicapped by landmines. The objective is to design portable, low-cost assistive devices that solve physical and socially stigmatic problems for handicapped individuals using a pit-latrine and be constructed in Uganda, by Ugandans. The project began in 2015, with the primary involvement and activities being designing and constructing prototypes. In January 2016, three prototypes were taken to Uganda to receive feedback and design revisions from the actual future users of the devices, handicapped Ugandans. Currently, the project is finalizing multiple designs for implementation and realization. The economic plan includes a livelihood support stipend to train Ugandans at a vocational school so that they can acquire the skills necessary in order to produce these devices. Landmine survivors can subsequently construct and sell the devices to attain financial independence. The project's design constraints include economic, engineering, and social limitations. The skills necessary for similar endeavors are adaptability, cultural sensitivity, and continual maintenance and reinforcement of project vision and goals.

Keywords— Landmine, Survivors, Assistive, Latrine, Prototyping

I. Introduction

Ongoing war and conflict has left Uganda with an overwhelmingly large handicapped population, as both rebel militia and government armies use and have used landmines to injure the opposition. However, this guerrilla warfare tactic kills and maims indiscriminately, affecting civilians more often than militant forces (80% of landmine injuries are to civilians) [1]. For those who survive an encounter with a landmine, losing one or more limbs is a common outcome. Those citizens left disabled by landmine accidents and attacks face a broad spectrum of difficulties due to their physical limitations. In the fall of 2014, Margaret Orech, founder of the Uganda Landmine Survivors Association (ULSA) and survivor herself, shared that the hardest challenge of adapting to life with a handicap was using the pit latrines [2]. This issue causes embarrassment, pain, and loss of dignity to those who need assistance using pit latrines because of missing limbs and other disabilities. For the nearly 32 million people of Uganda who reside in rural areas [3], the facilities typically available are pit latrines-a simple hole in the ground surrounded by a rudimentary structure providing privacy and some safety. For those who are impaired and unable to squat, balance, or to stand back up using their own strength, the use of these latrines without the help of another person is essentially impossible. To avoid embarrassment, many of these disabled individuals instead choose to relieve themselves in situations that increase their vulnerability, such as in the jungle or late at night. This, in turn, exposes them to other dangers including snake bites, wild animal attacks and even sexual assaults. Additionally, as they are not able to elevate themselves above the waste on most pit latrine floors, the physical limitation becomes a health and sanitation concern for these individuals. Furthermore, according to the International Classification of Functioning, Disability and Health (ICF), 19% of the Ugandan population is estimated to have a disability [4]. This means that almost 6 million Ugandans are dealing with this issue.

The necessity for a portable latrine-aid stems from a combination of obstacles facing the peoples of Lira. There is little infrastructure for those living with disabilities, so the likelihood of permanent installations being built to accommodate physical limitations is low. Individuals with mobility handicaps, which comprise 34% of disabilities in Uganda, are limited to being employed in areas near to their homes [5]. Assistive technologies, when appropriate to the user and the user's environment, have been shown to be powerful tools to increase independence and improve participation. A study of people with limited mobility in Uganda found that assistive technologies for mobility created greater possibilities for community participation, especially in education and employment [6]. Furthermore, during the research trip in Uganda performed within the scope of this project, potential users indicated that they would want their own device that they can take home after use at the pit latrines. A majority of the Ugandans that provided information do not have their own private bathroom; therefore, they are afraid that a permanent installation would be used by others and not properly maintained. Recognizing these realities, the solutions designed in the scope of this project seek to enable those who are handicapped by providing a portable device.

This project created a solution that is two-fold. The latrine-aid device solves the physical limitations of handicapped individuals face when using a pit latrine, while also creating a job market for the production of these devices in Uganda. In the past ten years, the people and government of Uganda have made strides pertaining to the rights of peoples with disabilities [7]. However, a negative social stigma against the disabled still lingers as the disabled are sometimes seen as a burden and unable to be self-reliant. The creation and production of these devices will allow landmine survivors to support themselves with the income made upon selling the Simple Seats. “Disabled people in Uganda, as in most developing countries in the world, face extreme conditions of poverty, have limited opportunities for accessing education, health, suitable housing and employment opportunities” [7]. This system will restore independence to the landmine survivor, and combat the negative social stigma of disabilities in Uganda.

II. Prototyping

A. Initial Designs

The problem is intricate. The solution must be portable and lightweight so a handicapped individual could move it. The device must also be low-cost so a Ugandan with an average, or less than average, income can afford it. The device must be producible in Uganda, by Ugandans, using local materials and tools. It must be socially acceptable to use. Lastly, it must be stable enough to support the full weight of an adult. The first concept of the device was a PVC model with telescoping supports. This idea was to make a device that could manufactured with materials that are both readily available as well as nonabsorbent to lower the probability of transmitting bacteria to the user (Figure 1).

The model was unstable and the PVC tubes would flex too much under small loads. The braces necessary to support the device would be too costly. The design needed to be changed. Constant communication between Orech and the members of the project was established to ascertain more information specific to Uganda and the resources there.

Fig. 1. PVC Prototype

Orech indicated that wood was commonly used to build furniture. The group conducted additional research on organic materials native to Uganda that could be structurally sufficient. Rattan, the solid root of bamboo trees, was found to be in abundance in Uganda. The group obtained 27 ft. of rattan to construct the next prototype. As the PVC model, when “retracted”, occupied a minimum volume of 22” by 11” by 12”, it was decided that the next design should have one dimension less than 4” in length. The device needed to collapse into, or as close to, one plane of thickness 4” or less. The next model was designed to rotate from the folded configuration to the seat from two axes (Figure 2). The design included handrails that extended perpendicular to the plane where the toilet seat sat. The handrails were intended to have the secondary functionality of being used as backpack straps for transit. Excluding the handrails, the total folded “thickness” of this design was approximately 3.75”.

Fig. 2. Rattan Prototype

After sending pictures and videos demonstrating the operation and use of the device to Orech, she relayed that the social stigma of carrying a toilet seat on one’s back would be too severe to justify use. Upon review, the precision necessary to place the pivot joints in the second model would be an obstacle in rural manufacturing. Additionally, the pins for the pivot joints took multidirectional shearing forces. As rattan is cylindrical, it is difficult to affix connections to exactly perpendicular to the surface.

B. Prototypes for Uganda

The next idea was modeled after a cardboard box. A cardboard box easily collapses into a singular plane, and because of its shape is able to take large vertical loads, especially relative to its weight and thickness. Wood and hinges were used to mimic the folding of a cardboard box. There were 7 hinges in total, two in the middle of the right and left sides, one in each corner, and one for the seat/top to rotate on. The first five allowed the sides to fold and become parallel and sandwiched between the front and rear panels. The top rotates 270 degrees and rests against the back panel. Handles were added on either side of the seat to allow the user to lower themselves on to the seat (Figure 3). A drawback to this prototype is the cost of materials. Hinges are expensive, and the only available wood in the region of focus in Uganda is hard wood, which is also costly. Using ½” thick wood boards, the box had uniform base widths of 20” and a height of 22”. The height to sit on is 22.5” as an additional board would fold on top.

Fig. 3. Folding Box Prototype

Another approach was considered as an alternative to a device solely used for sitting. The concept was a walker that would be used as a device that assists with transportation in addition to functioning as the latrine-aid. The design included a seat that would rotate out of the front frame that could be used at a latrine. The seat rests on the frame to transfer the load to the supports. The motivation was driven by the right angle joints that don’t require high precision to provide sufficient support. The front of the walker was rectangular with a base width of 24” and a height of 42”. The sides of the walker extended perpendicularly from the front and were rectangular with base lengths of 15” and heights of 42”. The seat was constructed with wood board and rotated out of the front of the walker at a height of 24” above the ground (Figure 4).

Fig. 4. Walker Prototype

C. Current Designs

During this research trip, the team kept a journal of the conversations that took place between with the beneficiaries as they provided feedback about what they liked and what they didn’t liked about the design of the devices. Utilizing the participant-observation research methods, improvements could be made to the devices to increase the likelihood of use as well as ease of manufacturing. The questions directed at the beneficiaries were:

1. Would you feel comfortable using this device in a public pit latrine?
2. How easy is it for you (or the user) to transport and use the device?
3. Are there aspects of the design that you would change to make it more accessible?

After the survey and introduction trip in Uganda in January 2016, the prototypes needed to be revised. The Ugandan feedback and critique of the walker design was that it was too wide to fit in all pit latrines, the seat needed to be wider, and the material needed to be changed from rattan to metal. Welding aluminum is not uncommon in Lira. A more robust solution was designed to replace the design. A crutch was designed with a seat that would fold out of the frame. The motivation was to maintain the duality of a transportation and latrine-aid assistive device while simplifying the design and not being limited by uneven terrain (Figure 5).

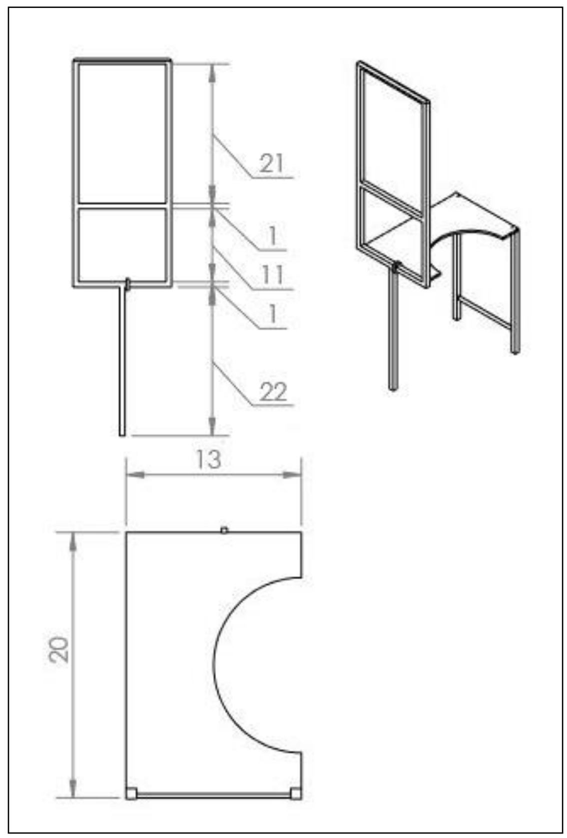

Fig. 5. Crutch Design (*Dimensions in Inches*)

The box prototype remained, but after learning rattan is not used, the handle construction was changed to wood. New geometric shapes were created for all of the sides. These shapes simultaneously save time by performing fewer cuts, and also use less wood which lowers the cost. The side from which the user swings the seat on to the top of the four sides was placed on the opposing parallel side. This makes it easier for the user to open it in a latrine due to the confined space (Figure 6).

Two designs are pursued due to the feedback from potential users indicating preference varied between disability types. For the crutch and folding box designs, approximate maximum loads were calculated using stress-analysis stemming from basic theories of material mechanics. For the crutch, the first failure would be a bending fracture in the middle of the seat. A point load approximation in the center of the seat was used to estimate the maximum load. The following equations for stress due to a bending moment and the definition of stress

$$\sigma = (M \bullet y)/(I_x) \quad (1)$$

$$\sigma = F/A \quad (2)$$

where σ is stress, M is the moment, y is the distance from the neutral axis to the outermost fiber, I_x is the moment of inertia about the neutral axis, F is force, and A is cross-sectional area were used. For the box, the failure mode would be yielding under compressive stresses; "(2)" was used to approximate the force required to induce yielding. The following table summarizes the characteristics of the box and crutch designs that are pertinent to the scope of this project.

TABLE I. CRUTCH AND BOX DESIGN SUMMARY

Design	Material Yield Stress (psi) [8]	Weight (lbf)	Cost of Materials ($)	Approximate Maximum Load (lbf)
Box	5320	12.5	10.32	540
Crutch	1130	8.75	8.83	215

a. Cost does not account for possible inflation quoted to our team as a result of being from America

b. Assumptions and simplifications concerning anisotropic nature of wood and complex geometries made

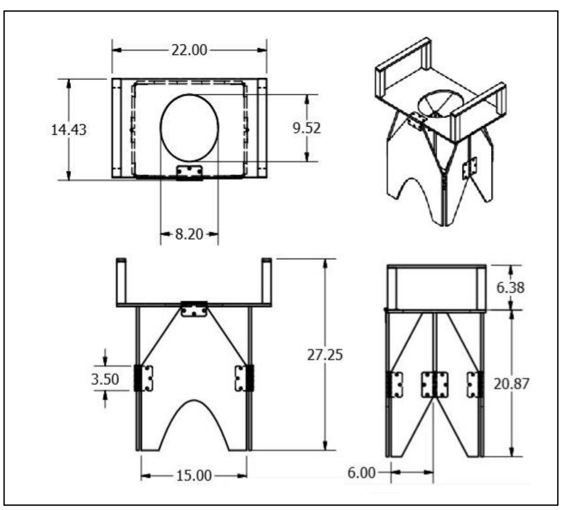

Fig. 6. Final Box Design (*Dimensions in Inches*)

III. SOCIAL IMPACT

The social aspect of the project is of as equal importance as the physical aspect and was also carefully considered in the design phase to alleviate any negative connotations associated with persons of disabilities and the latrine aid device. The limitations of a humanitarian engineering endeavor are often cultural boundaries. It is not a project aim to change the culture, but to improve accessibility for handicapped individuals. "When you reach a family with a disabled child, the parents say, 'We have four children and one disabled. The disabled child is not part of the family, they are an unfortunate addition," says Teddy, a woman who has first-hand experience with being abandoned by her family because she became handicapped, explained [9]. As a result of these negative stigmas, it is difficult for a handicapped individual to find employment, and as more disabled people have no other option other than begging on the street, these negative stigmas intensify. The other project goal is the restoration of independence and self-worth with these latrine aid devices. While in Uganda, the project team met with several vocational institutions and decided, alongside Orech, that a small private vocational school called Ave Maria was the best fit for this project. For handicapped individuals, it costs $12 for six months of vocational school training including with room and board. This tuition and materials for the pilot program will allow the landmine survivors to learn the skills needed to begin creating their own products and potentially start their own business. Thus, the objective of the project will be met as independence and dignity will be restored to the new entrepreneurs. This project can contribute to broader, deeper social issues and create a long-lasting impact. The pilot program is intentionally small to keep production of the devices manageable for both ULSA and the survivors building the seats. However, this project has potential to grow, as more landmine survivors begin producing the seats. Uganda is not the only country with problems of this nature.

IV. ECONOMIC SUSTAINABILITY

While meeting with Orech and ULSA in Uganda, Orech explained that ULSA typically provides approximately one million Ugandan Shillings (roughly three hundred United States Dollars), as "livelihood support" to the identified survivor [10]. With that livelihood support, the survivor can start a business of his or her choosing to support himself or herself. Survivors choose between options such as grains for farming, animals to breed and butcher, or clay for firing bricks. The economic model would use the livelihood support to send the survivor to a vocational school where they would learn carpentry and metalworking. The survivor would then begin producing the devices for revenue.

The pilot program for this project includes a budget for the first ten landmine survivors to attend vocational school. The stipend would also include the materials for each of these initial ten landmine survivors to each produce ten latrine aid devices that ULSA would then purchase from the survivor, at a profit to the survivor. ULSA would distribute the devices to other identified survivors in need of the device. Another benefit to this system is that ULSA already has a network across the country of landmine survivors, so it is much easier for the devices to reach a greater number of beneficiaries. Studies have shown that perceived value and quality of a product are increased if the product itself costs more [11]. By charging a small but affordable sum of money, the recipients will ascribe value to the device and take better care of it. Economic studies have also shown that communities that receive handouts become dependent and the ostensible aid becomes detrimental, and it is more effective to create a system whereby the impacted peoples participate and grow autonomously [12], [13]. This project is designed to empower the landmine survivors and restore independence by providing knowledge and skills rather than charitable donations without direction.

Furthermore, if the market for assistive devices were to be exhausted and no revenue could be generated for a survivor to subsist upon, the survivor could be employed or contracted as a craftsperson of carpentry and metalworking by others in the community. However, this eventuality is unlikely as the device can also benefit elderly and sick individuals as well, thus interfacing with additional markets. The tables below outline the budget the team expects the project will require.

TABLE II. COST OF IMPLEMENTATION

Pilot Program Cost	**Cost ($)**	
Item Description	***Cost Per Survivor***	***Total Cost (Ten Survivors)***
Livelihood Support	333.33	3333.30
Six Months of Vocational Schooling	12.00	120.00
Materials to Construct Ten Devices	150.00	1500.00
TOTAL	495.33	**4953.30**

TABLE III. TOTAL COST

Project Cost	**Cost ($)**
Implementation Cost	4953.30
Prototyping Materials	400.00
Approximate Shipping Cost	2000
GRAND TOTAL	**5553.30**

V. FUTURE WORK

The project is ongoing and entering the implementation stage. The current scope of the project is finalizing the construction of the prototypes, creating pictorial manuals detailing the manufacture of the prototypes, and the shipping of the prototypes with the manuals to Orech and ULSA so the pilot program can begin.

The primary research method while on the evaluation trip was taking notes, asking questions, and keeping a journal of all responses and reactions. This project generated knowledge about the different aspects of the relationship between a group of humanitarian volunteers and the group who is being impacted by these volunteers. The project includes exploring the steps to take to ensure that this relationship is most beneficial for both parties and that a project is successful. For example, as discussed during the design process, the social and cultural characteristics of the device's beneficiaries were treated with supreme importance.

VI. CONCLUSION

Projects that identify and seek to assist specific afflicted groups of people can increase the effectiveness through extensive communication. Engineering projects have a tendency to focus on the problem rather than those affected by it, and what appears to be a viable solution through the looking glass of an engineer from a different culture may not be viable to the user. Extensive communication includes sharing prototypes and design direction, soliciting feedback concerning not only each design but each iteration, and, in the case of a distant community, an effective project survey of the region in person. The project discussed above would have benefitted immensely from a detailed accounting of resources and tools available in the target region. One major assumption made during the initial design process was assuming the builders would only have simple tools limited to a hammer, saws, and nails. During the survey trip in January 2016, this assumption was proved to be incorrect. In Lira, the rural region for the pilot program, many individuals are skilled in arc welding aluminum and steel. The design review after the survey trip allowed for the Crutch design that utilized the metal frame for significantly stronger material properties. Additionally, learning that rattan is not commonly used changed the handrail features on the box design.

For all humanitarian projects, it is imperative to ascertain as much first-hand knowledge as possible to maximize the effectiveness of prototyping time and cost. If first-hand knowledge is impractical, explicit and extensive information gathering from local contacts is essential to operate under reasonable assumptions and design constraints. Design changes and directions must consider the impacted people and cultural norms. An engineering solution that solves the mechanics of the problem but is unused due to a social or cultural stigma is not an effective solution. The second design of this project had to be changed due to the stigma of carrying a toilet seat on one's back. To create a longer-lasting and sustainable effect, the project should include an economic plan that enables the target community to autonomously continue or maintain the work started during the pilot phases of the program.

To sustain and execute a humanitarian endeavor, it is also necessary for the members of the team to function coherently during design and construction. Patience and consistent affirmation of the project goals and objectives is useful for motivating individuals to regularly produce high quality work. Prototype deadlines and expectations should be clearly laid in in monthly or bi-weekly meetings to hold members accountable for delivering materials to advance the project.

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