The One Wheel Drive Initiative: An Overview

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I. Introduction

In sub-Saharan Africa, 50% of people live on less than one dollar per day. With much of the region's labor force engaged in subsistence-level farming, the agriculture industry holds a key to improving the lives of millions of people.

In the summer of 2009, Doctor John Morrell, an engineering professor at Yale University, spent several weeks in Ghana and Kenya with an interdisciplinary team assembled by the Meridian Institute observing farmers at work. They recognized several possibilities for improvement. First, the vast majority of work was done manually, with no mechanized farming equipment to perform tasks such as milling, grinding, or drying. Second, the mechanized tools that did exist each required a separate power source; that is, one engine was hooked up exclusively to one device. Third, there were a number of sources of mechanical power such as bicycles and cars.

At the One Wheel Drive Initiative, our mission is to address these inefficiencies and gaps in power usage on two levels. On a small scale, we aim to harvest energy from off-the-grid, pre-existing sources (such as a bicycle, motorcycle, or engine) and transfer it to multiple and many power-consuming appliances (such as cell phones, mills, and dryers). On a broader scale, we hope to standardize the way in which these devices connect to create a platform for open-source innovation on the ground by actual users.

We look to accomplish these goals through the use of a novel yet simple mechanical standard, an intermediary device we call a "linkwheel."

This report is intended as a conceptual overview of what a linkwheel is, the overarching system that encompasses it, and how they will help subsistence-level farmers in sub-Saharan Africa. It will also give a brief description of work that has been done towards the initiative and future work we hope to accomplish.

II. The One Wheel Drive System

At the One Wheel Drive Initiative, our functional goal is to decouple power sources and power-consuming devices. Because of the prohibitively high cost of an engine (over $150), purchasing multiple mechanized tools is not financially feasible for the typical smallholder farmer. Separating the source and device gives farmers the chance to drive multiple tools with a single power source.

The One Wheel Drive (1WD) system hopes to give farmers precisely that opportunity. It consists of three interrelated parts:

1. an object called a linkwheel
2. the mechanical standards that define the linkwheel
3. devices compatible with these linkwheel standards

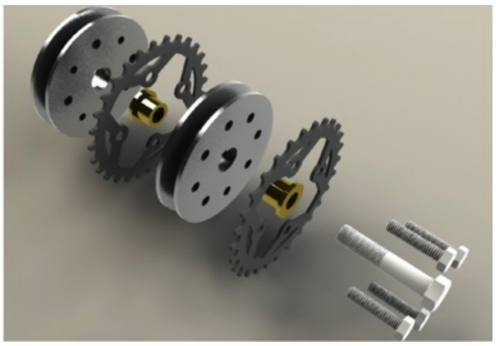
1. What is a linkwheel?

The linkwheel itself is a simple object you can hold in your hand. It is fundamentally a coupling comprised of two pulleys and two sprockets bolted together that can connect with a variety of common belts and chains. It also has a keyed shaft and a bolt circle, providing two additional means of connecting with the linkwheel. Through these various joining pieces, a linkwheel can simultaneously connect a power source to different power-consuming devices via rotational power.

For example, a linkwheel can be driven by a bicycle hooked up through a chain. The pulleys on the linkwheel could then be used to attach belts from any number of appliances. Alternatively, the linkwheel could be directly bolted onto a spinning component of the appliance itself. There are numerous configurations possible with a linkwheel, instead of the typical 1:1 ratio of engines and tools. Because the linkwheel homogenizes the form of the power output, any power source with a spinning component can be used.

A useful way to think about a linkwheel is the mechanical equivalent of an electrical outlet. In the developed world, outlets act as an intermediary standard between the power grid and most power-consuming appliances. Instead of electricity, though, linkwheels use rotational power. The electrical grid is replaced with a variety of common and accessible power sources such as motorcycles and engines. The belts and chains used to transmit rotational power from the source, through the linkwheel, and to the implement can be thought of as the electrical lines and power cords running to and from electrical outlets.

2. What are linkwheel standards?



The linkwheel standards are dictated by the technical specifications that allow devices to connect with the linkwheel. Currently, the linkwheel is compatible with ANSI 40 chains and D standard v-belts, two common sizes in sub-Saharan Africa. The standards also govern dimensions such as the diameter of the linkwheel and its bolt pattern.

To continue with the electrical outlet analogy, in the United States every outlet accepts the same three-pronged plug shape as dictated by the American National Standards Institute (ANSI) and the National Electrical Manufacturers Association (NEMA). All manufacturers of appliances in the US use that plug type because they know their customers will be able to access the power grid with it. Thus, they do not need to devise a unique connection to the power grid for each appliance they make. The standardization also benefits consumers, as they can expect any appliance they purchase to conform to the outlets they have in their homes and need not worry about how they will power each appliance. For electricians, standardization eliminates the complications of having unique electrical networks in each home: the voltage, frequency, outlet size and outlet shape are uniform.

As this electrical outlet example demonstrates, standardization can benefit all parties involved by establishing common design expectations between them. With the linkwheel, we hope to take advantage of the power of standardization to create an analogous system. Since no underlying power standard exists in sub-Saharan Africa, the linkwheel aims to gather local types of common chains, belts and bolt patterns that already exist in developing countries into a single device with a single bulk standard. It is an outlet that accepts not just one, but several different types of plugs. We hope that manufacturers, mechanics, and end users alike will benefit from such linkwheel standards.

3. What are linkwheel compliant devices?

Linkwheel compliant devices are power sources and power-consuming appliances that are compatible with the linkwheel standards. Virtually any power source with a rotating shaft (bicycles, motorcycles, automobiles) can be adapted to drive a linkwheel. Similarly, many devices can be modified to run off of a linkwheel, such as water pumps, mills, and alternators.

Thus far, we have designed and modified a number of products to be linkwheel compliant. For power sources, we designed a set of friction rollers to harness the mechanical energy of cars and motorcycles. To transmit power from a bicycle, we extended the existing bicycle chain to wrap around a sprocket on the linkwheel. Several pre-existing

agricultural appliances already run off of rotational power, so we modified their drive mechanisms to be linkwheel compliant. For example, we replaced the hand crank on a mill with a sprocket, and connected it with a chain to a linkwheel mounted on a bicycle. For electrical applications, we reworked automotive alternators to convert our rotational power to electrical power. Through this alternator, one could charge a 12-volt battery that would power small appliances as a cell phone charger or LED lights. We have also developed a novel cassava dryer that runs on 12V fans. As our examples show, a broad range of tasks can be accomplished using linkwheel compliant devices, and there is far-reaching potential for many more.

4.Building an Environment with the 1WD System

While the functional goal of the 1WD system is the decoupling of power-source and power-consuming device, there is a broader goal at play. We hope to encourage an environment where the 1WD System is ubiquitous, and the linkwheel was developed with this goal in mind. For example, rather than relying on manufacturers, virtually anyone who wants to experiment with a linkwheel can construct one with spare sprockets and pulleys. Once armed with a linkwheel, the 1WD System can be adapted to fulfill a wide range of needs. In the spirit of open-source innovation, we hope that new linkwheel compliant devices will continue to be built. We also envision entrepreneurs creating a business centered on the 1WD System: perhaps a motorbike taxi owner traveling from farmer to farmer, renting out usage of his motorbike to power tools or charge batteries.

Standards are crucial to the potential for open-source innovation because they provide a foundation for development. With knowledge of the linkwheel standards, farmers, mechanics, and entrepreneurs alike can adapt the 1WD system to their liking. Such mutual understanding between creators and users encourages continual development by stakeholders and an atmosphere of co-creation.

III. Why 1WD?

In order to promote adoption, we designed the 1WD System to fulfill three primary criteria. First, it must be viable and work with the existing infrastructure, culture, and economies in sub-Saharan Africa. Next, it must be accessible in the short-term: affordable and easy to use. Last, it must be sustainable in the long-term and independent of external aid. We believe our project is appropriate for the sub-Saharan Africa environment because it satisfies these three conditions.

We believe the 1WD System is viable because we analyzed the mechanical fabrication industry, current methods of transportation, the agriculture industry, and the livelihoods of smallholder farmers for characteristics that would shape our project. Some of our discoveries acted as constraints. For example, in the transportation sector, we found that access to automobiles in sub-Saharan Africa is relatively rare. Accordingly, we did not build a solely car-dependent system. Our studies of the mechanical fabrication industry revealed that machining was limited to welding and simple cuts. We took other aspects of existing systems as opportunities: the shortcomings of the electrical grid meant a niche existed for alternate power solutions. We learned that many agricultural processes are done manually on the small farms we analyzed, but could be mechanized easily. The 1WD System uses these existing conditions as a springboard to change the current energy structure.

To make the 1WD System accessible, we focused on making it affordable and easy to use. Accordingly, linkwheels are inherently simple and made of local materials and parts. The easily obtainable parts make the linkwheel cheap, and local machine shops and mechanics have the skills to build linkwheels and linkwheel compliant devices. These qualities make the 1WD System affordable for the end user.

Because the 1WD System does not require the purchase of an additional engine, the cost of entry is greatly reduced. For example, a linkwheel compliant maize sheller can be purchased for $20 and a pre-owned bicycle can be used to power it. Alternatively, if the sheller is already owned but used with a hand crank, it could be modified to be linkwheel compliant for approximately $10. Later, with the profits generated from the mechanized sheller, an engine or motorcycle could be bought to power a heavy-duty mill. This sort of scalability, from low-power to high-power and low-cost to high-cost, is another advantage of the 1WD System. The transparency of the 1WD System ensures that any end user can understand and immediately use the system; one need only understand how to connect a belt to a pulley and a chain to a sprocket in order to use it. In combination with the low financial barrier, the system's scalable and transparent nature makes it accessible to virtually anyone.

The 1WD System's sustainability derives from its flexibility, ease of repair, and opportunity for innovation. The parts are largely interchangeable, so substituting a motorcycle for an engine or a chain for a belt will not affect the system's functionality. This flexibility makes the system durable: one broken-down part will not render the entire system useless. Since the design requires only basic machining capabilities and is constructed of local materials, it would be easily repairable. By using local materials and skills, we ensure that the economy of the 1WD System remains local and supports the community where it is used. Having local stakeholders is critical to sustainability.

We hope that the 1WD System can eventually be sustained on the grassroots level with no need for foreign aid. Our measure of success is when the community using the 1WD system starts innovating around it. Since parts are available locally, the design is simple and transparent, and the system is flexible and scalable, we believe the 1WD System can inspire open-source innovation on the ground. If such innovation occurs, it will surely increase the sustainability of the system by actively involving the end user.

IV. What We've Done

The idea for the 1WD System was introduced to an interdisciplinary class of 18 students at Yale University in the spring of 2011. After a concept-generation phase, the class was split into two teams: technology and commercialization. This unique class structure allowed us to cover not only design tasks, but also the market analyses and economic factors that can sometimes be overlooked. Both teams strove to develop simple yet valuable applications for the 1WD System.

Technology-focused class members spent the semester designing linkwheel compliant devices, both power-producing and power-consuming. Although our ultimate goal is open-source innovation, we first needed to create these appliances and devices to serve as an example of the potential of linkwheels. We hope these examples will provide a springboard to launch the linkwheel standard to consumers and manufacturers and act as a spark for innovation.

The commercialization team provided an economics-focused perspective on how we could fulfill our objectives of viability, accessibility, and sustainability. We analyzed which materials would be most affordable and how mechanizing tasks could alter the income of a smallholder farmer. Several commercial team members were also responsible for constructing a business and dissemination model for the One Wheel Drive Initiative.

V. What's Next?

Our semester-long mission at Yale was to demonstrate that the 1WD System can be useful while establishing a foundation for further development. Because we were working in a classroom, it was impossible to prove that our specific appliances would work on the ground in sub-Saharan Africa. While we did all we could to estimate and minimize supply and labor costs, working from overseas presents inevitable restrictions.

Accordingly, our first goal is to spend time in sub-Saharan Africa to analyze our work thus far. We must be on the ground in order to learn whether our understanding of manufacturing capabilities was correct and whether our products work in the sub-Saharan environment. Evaluating our devices and our assumptions is unquestionably our next step. This initial testing and fact-finding trip will also serve as a chance to get input from stakeholders and begin the process of co-creation.

With the knowledge acquired from this trip, we can begin our second design phase, improving on our original models and reexamining our pricing estimates. Once we have satisfied these short-term goals, we can then turn to a long-term deployment strategy. We propose establishing an umbrella organization to oversee the 1WD System's development and dissemination. Working with partners such as the Meridian Institute and East Africa Dairy Development, this organization would build relationships with various stakeholders, including manufacturers and smallholder farmers.

We believe our project has enormous potential to improve the livelihoods of sub-Saharan Africans living without access to the electrical grid. Our work is only the first step in validating the 1WD System. Spending time on the ground will enable us to test our appliances and take the next steps towards realizing our goals.