

Development Design Lab

Optimizing Existing Networks in E-waste Management to Establish a Circular Economy

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Dedication

The WPI students would like to sincerely extend thanks to our NUST student partners, Tumelo, Frank, Edwin, Faith, and Emeka, for their contribution to this project over the last seven weeks. This project would have been impossible without the direct collaboration between both student groups in the United States and Zimbabwe. We would never have had access to all the information received through interviews and surveys if it were not for all of your hard work reaching out and traveling to different locations. We thank you for your dedication to this project and to making a difference in your own community. It was a privilege working with you all and we look forward to providing input on future extensions of this project with you. We hope one day we will be able to meet in person, but we are grateful to you for providing us with an unique experience comparable to actually being there. We will miss our morning meetings and seeing you all so often, but we wish you the best and look forward to continuing to grow this incredible friendship.

Authors' Note

This report uses words like “we,” “our,” and “us” countless times, so it is important to note that any use of these or similar words refer to all team members, both from Zimbabwe and the United States. This project and report were possible only because of the co-design between the whole team.



Image depicting the sign entering the Richmond Landfill.

Creating Sustainable Economic Opportunities Through Local Action

“Resources are not; they become.”

– Erich Zimmerman

The last decade has seen a significant increase in electronics usage across the world’s developing nations. For countries without proper management of e-waste, this has immense consequences, particularly in many sub-Saharan African nations that have also become the primary destination for e-waste exported from developed countries. E-waste processing exposes people to highly toxic chemicals and heavy metals, which can have detrimental effects on the systems of the human body. However, e-waste is not something simply to be disposed of; it provides economic opportunities, as it can be refurbished and resold, dismantled and repurposed, or broken down into valuable precious metals. E-waste recycling is a lucrative business, especially as it is one of the largest and fastest growing sources of waste worldwide. It was reported that 44.7 million tons of e-waste was discarded domestically across the world in 2016¹. As a result, the business of e-waste processing has become the main source of livelihood for countless people in developing nations, one example being in Bulawayo, Zimbabwe.

Within the city of Bulawayo exists a valuable network of electronics, but in most cases the devices that enter the city are managed inefficiently or leave the country altogether, taking immense value with them from the people of Bulawayo. Sometimes outside manufacturers and companies buy Zimbabwe’s waste for far less than it is worth, then proceed to sell it back to them as a refurbished product². Because of the economic opportunities of e-waste, we wanted this network to be as self-sufficient as possible so that Bulawayo could maintain as much value as possible. Our purpose was to do things locally so that communities could have efficient and sustained economies. This did not necessarily mean having all processing done in Zimbabwe, because it is dependent on a country’s infrastructure and resources, but it was important to understand where this business could be improved for those in Bulawayo. Figure 1 shows a broad representation of the network revealed, but we want to emphasize in this report the co-design process we went to actually produce this graphic legitimately. Uncovering this network indicated where value is being lost and aided in identifying points at which to enter the network with this project. The network also demonstrated that our purpose with this project was centered on this value. After learning about design and development, and once we started looking to our project and applying what we had learned, we realized our project was not about building new infrastructure or introducing new systems. It was about using the already existing culture of repair and reuse in Zimbabwe to increase the revenue of e-waste processors, redirecting parts of this network to keep its value contained within the country and ensure a self-sufficient and sustainable process. However, we did not arrive at this understanding right away. We only found the big picture of our project, the purpose underlying all of our work, with constant iteration between research, brainstorming, planning, and action, like with any proper use of design.

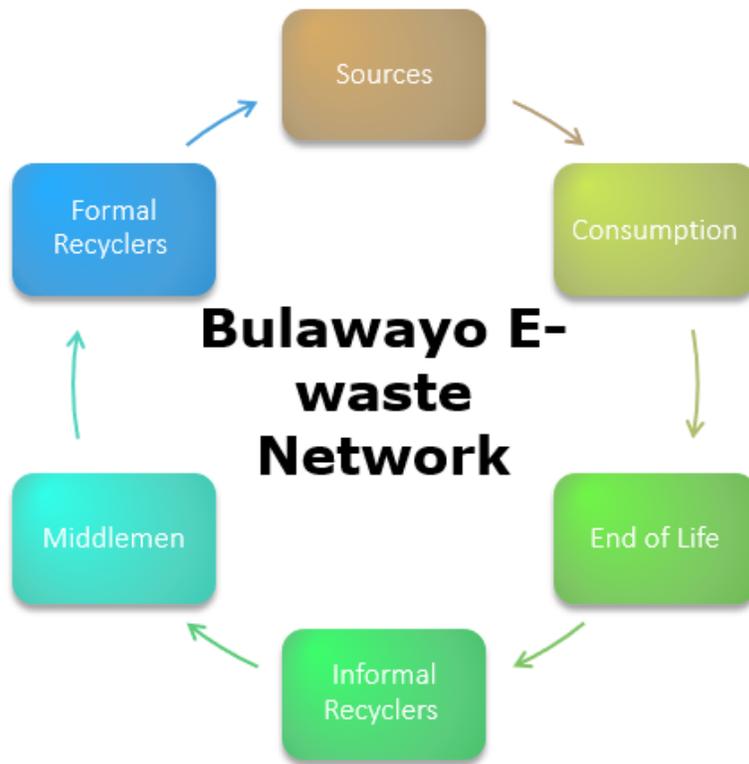


Figure 1. A broad representation of the e-waste network within Bulawayo, Zimbabwe

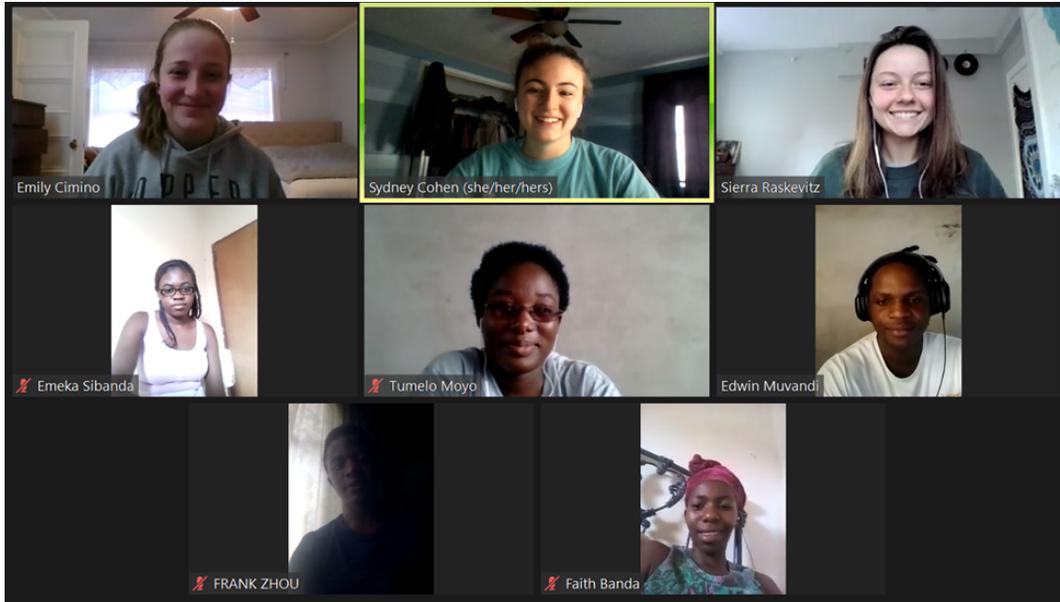


Image depicting all eight team members from NUST and WPI meeting over Zoom.

Co-design: A Priceless Practice

Development and design have had many interpretations. Design was once thought of as having a creative disposition rather than being skillful and having experience in the trades. This was especially prevalent during the Stone Age when people made and used tools to accomplish tasks. During times of colonialism and imperialism, development was associated with the creation of new societies, though this had both positive and negative connotations. The term development, in general, was used to describe actions by colonizers tracing back to the 1400s when colonialism and imperialism began to spread across the world³. Imperialism was implemented as a way to prevent communism, which the Western world claimed was a major threat to civilization. It was believed that the only way to “save” countries from communism was to force on them the innovation of capitalistic developed countries⁴. This type of development harmed natives, destroyed property and lives, spread disease, and erased deep rooted culture in order to build an ideal world as defined by developed countries.

This is still prevalent today as cities are being modernized and gentrified, causing a loss of culture aligned with rich history and stored in art and architecture⁵. There also still exists the racism and bias that began when Americans saw people of Africa, Central America, and other underdeveloped areas as less-than, resulting in the imperialist mindset of wanting to help them. These were countries that did not have the same values or systems, so developed countries wanted to prevent them from conforming to communism. Along the way, they classified countries by their per capita income which led to the concept of First, Second, and Third World nations. International development began after the Second World War, before the Cold War, when colonialism turned into globalization⁶. Fundamental issues of design for development were addressed as designers acknowledged that development is not one size fits all. Attempting to develop “third world” countries in the same manner as “first world” countries was unsuccessful as many aspects of individual countries are not interchangeable, such as available resources, funding, environment, and culture. Rather than attempting to take solutions from a country with immense infrastructure, technology, resources, and funds, and applying them to “third world” countries that do not

have the same resources, designers have now started to design for who and where their work will impact. In doing so, they consider the diversity, ethics, capabilities, and obstacles of said people and places.

“Do your job to the best of your ability, and remember you work for the people who will ultimately come in contact with your work.”

– Mike Monteiro

Co-design means to design by working with others. Co-design ultimately allows for cross-cultural generative design as it allows all people involved to be considered. Generative design or generative justice is the ability to create value and directly reap the benefits since it is not solely the designers involved in the process⁷. Figure 2 explains how co-design factors into the traditional engineering design process, which is at every stage. Whether defining a problem or testing a design, it is important that designers engage with the people that their work will impact, as even the best research done by outsiders cannot compare to the experience of those whom the design will affect. Designers are limited in their knowledge and can only understand what directly affects them. Gaining perspective from the people who live in the area and those who will be impacted by the design is therefore invaluable.

Thus, no matter how much research the U.S. students did prior to teaming up with Zimbabwean students, they would never understand the full scope of circumstances surrounding this project. With such a large team, our co-design process benefitted from a wide range of ideas and experiences, though it was a challenge to incorporate every idea all the time. Co-designing through this partnership has not only allowed us to gather information about the Bulawayo community that could not have been acquired without it, but has also provided a connection that will surpass the scope of this year’s work and carry over to all future work on this project.

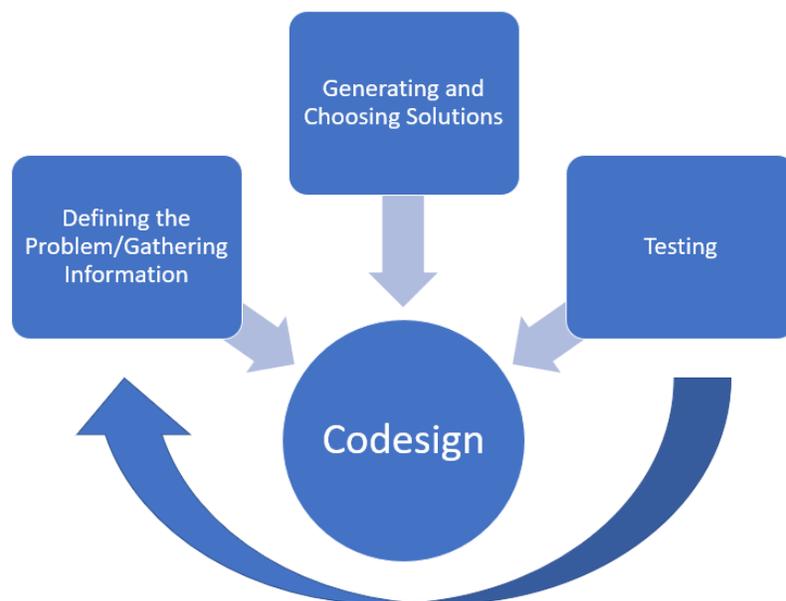


Figure 2. A graphic of how co-design interfaces with the engineering design process.

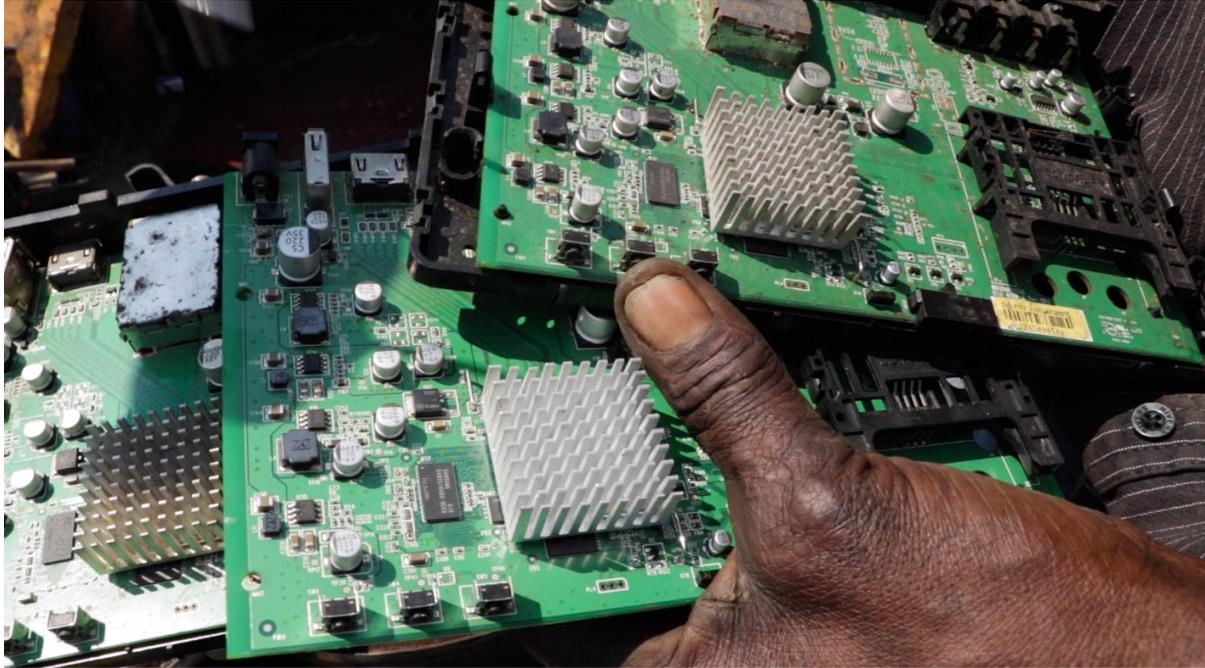


Image depicting circuit boards being held by a local.

The Dynamics of Co-design

As the end of the project approached, we realized that our current goal was far different than what we originally anticipated. Before the project began, the U.S. students were mainly focused on the adverse health and environmental effects of improper e-waste handling in Bulawayo and what systems could be implemented to mitigate that. They conducted research by consulting peer-reviewed literature, news websites, and articles to gather information on the purpose of the project. Finding the health risks of improper e-waste handling, dismantling, and material extraction led them to believe that we needed to eradicate this system. With the knowledge that workers were making money off of this toxic line of work, we wanted to find alternative means of earning an income in this field that would reduce the air, water, soil, and food pollution. A repair café, like the ones held for free in the United States and other developed countries, would be a means of collecting and processing the waste that would not produce toxins known to cause kidney disease, liver disease, heart damage, and birth defects. The existing repair cafes in the United States are volunteer-based, but our idea was to create a business model based on the technical principles of the repair cafes while allowing the technicians to make money from fixing the broken equipment and selling it as functional devices.

With this idea in mind, we started brainstorming models and plans that we thought would be comfortable and well received by the community and the e-waste workers specifically. We negotiated titles based on local vernacular, discussed location and the community's comfort with security, and debated the incentive for locals to change the routine they were comfortable with. However, we found that immediate action would not be beneficial and we needed to step back and understand the entire pathway of e-waste in Bulawayo before trying to enter at a certain point. Entering the business and trying to change things would not be an efficient or smart way to try improving the economy. We investigated deeper into the network of the e-waste within and outside of the city of Bulawayo to understand where the

value lies, where it is lost, and where the repair shop could be implemented. It was not until we started doing this digging that we realized this network was the main goal of our project at the end of our seven weeks. This network was such a valuable component that it deserved more attention than just being a step in the process.

“View [this concern] not as an impediment, but as a welcome challenge for innovation.”

– Chakenetsa Mavhunga

Once we realized that this network was our main focus, we set out to uncover it. But even though this was our final confirmed goal, our understanding of it continued to evolve. At first, we created linear representations of the network, but this did not align with how it is meant to flow because a line has an end, and we want the value of e-waste to always be moving around the city. Otherwise the value would disappear or get stuck and not cycle back to the start. This led us to realize the concept of the circular economy that we were trying to amplify, because in a circular economy, the value is able to continually move. The existing circular economy of Zimbabwe’s e-waste business did have points from which value was lost to other countries, but we learned that this was necessary. So while we know it is not currently possible to contain all e-waste value within Bulawayo, we want to minimize the value lost.

The network took many weeks and multiple interviews to uncover. We planned a symposium to gather e-waste stakeholders of different statuses to have a discussion about their roles in the network. The event took a week to plan with flyers, language specifications, COVID-19 safety guidelines, budget, and even T-shirt designs, but because of the rigid COVID restrictions, the event was unable to be carried out. The information we were hoping to find at the event was gained through email or What’sApp interview instead of organic dialogue. Though this meant we were not able to talk with as many people, we believe we gained more from those that we were able to talk to because there was anonymity. Participants likely would have been reluctant to disclose information about their work at an in-person event. Overall, doing the project remotely aided us in gaining information that may have remained undisclosed if the project were done in person and with only U.S. students. Co-design ultimately allowed us to dive deeply into the system, and the Zimbabwean partners were the key to proper communication, facilitating comfortable bonds with the e-waste stakeholders, and providing technical knowledge that aligned with local values.



Image depicting a waste picker being interviewed and his bag of e-waste.

Co-design in Action

“Design must be domesticated, not adapted.”

– Chakentesa Mavhunga

Collaborating with Zimbabwean partners revealed aspects of their culture that the U.S. students would never have discovered as outsiders, beginning even before any direct community engagement. At the first team meeting, we discussed and learned about Zimbabwe’s economy, both in general and with regard to e-waste, and particularly with regard to how people interact, which was very important in determining where to start the project. For instance, the economic climate in Zimbabwe is one of major competition, a “hustle” culture in a sense. Everyone works hard to grow their business themselves; experienced repair technicians, for example, have acquired an established customer base and their own rent space. With this being the case, individuals wish to ward off competition and are not keen on sharing information or skills for free. The concept of volunteerism does not exist in Zimbabwe as it does in the U.S., so this is where our initial idea of implementing a system similar to a repair café started to falter. It

was not necessarily a bad idea, but it would only ever be a framework to build from in Zimbabwe. The approach was not to take things that worked in the U.S. and find the Zimbabwean equivalent, but to work from the inside out and find things that are possible locally that can accomplish our goals. The WPI students had learned that design was about the people being designed for, but this initial meeting as a whole team was the first time the WPI students were really starting to understand the city for which we would be designing. This solidified the fact that we had to start from within the context of Zimbabwe and work out, amplifying the culture rather than disrupting it by trying to force outside ideas to be adapted.

From there, we were only ever learning, but through one particular interview conducted in an effort to uncover Bulawayo's e-waste network, we learned one of the most important things of this whole process, going back to our original visions for the project. We had imagined a main goal was to keep the value of e-waste processing contained within Bulawayo as much as possible. However, from an interview with a local e-waste buyer we learned exactly why e-waste is exported from Zimbabwe and why it is a necessary part of the process, at least for the time being. Zimbabwe does not have local recyclers like other countries do, and it is not currently feasible because they lack the infrastructure and funding necessary for the expensive equipment and dangerous processes. The buyer explained that because Africa adopted modern technology later than other continents, there is little available e-waste relative to other nations, so constructing and operating a large recycling factory in Zimbabwe would cost more than it would make. This taught us many things, particularly in how it informs future work for this project. As much as we would like the e-waste network of Zimbabwe to be self-sufficient, it is not yet at a point where it can be both sustainable and completely self-sufficient. The connection we hope to make between local recyclers/repair technicians and electronics consumers would gain more value for these stakeholders, but we cannot force the circular economy to exist only within Bulawayo. Perhaps a smaller scale recycling operation is possible in the future, but for now, exporting e-waste must remain part of the process.



Image depicting waste pickers collecting waste.

Co-design: An Imperfect Practice

*“We don’t see the world as broken because everything is made as it was designed and we designed it.”
– Mike Monteiro*

Figure 2 was a great look into the concept of co-design within the engineering design process. The engineering design process is not linear. Instead, it iterates between the different stages, allowing the designer to review their work constantly and return to any step. Most versions of the engineering design process contain very similar stages. They begin by defining the problem and gathering relevant information. As mentioned previously, we conducted research on the human and environmental health issues of Zimbabwe due to unsafe e-waste processing methods. Through additional research and interviews with locals, we realized that the e-waste business in Bulawayo was also losing value on the e-waste. It was often being exported to other countries as dysfunctional parts, and these countries were able to profit from the repair and repurpose these materials. This was something that Bulawayo could do themselves, and in that case the value associated with this work would remain within the city, generating more revenue for the community from e-waste.

After the problem was established, we conducted research and interviewed repair technicians in order to learn more about Zimbabwe’s e-waste business. However, we did so focusing on one solution, the idea of an electronics repair shop, which limited the design process. Because of this, our questions were mostly geared towards uncovering information relevant to that solution, such as preference for a stationary or mobile shop model, where people would have the most access, etc. Again, we had researched and brainstormed, so we thought this next step of gauging community interest might be the initial testing of that idea. However, once we started to interview people, we realized that we were lacking necessary community input at earlier points in our work, and our general understanding of the network of e-waste within and around Bulawayo was not strong enough. Even though we had a team consisting of U.S. students and Zimbabwean students, it was important that we spoke to the locals within the community, at all steps of our co-design process, so that we did not end up designing something of no use or interest to the people, that did not fit into the local culture. This was definitely a point for improvement

within our design process. We used co-design along the way working with a diverse team, but engaging with more stakeholders would have enhanced the process even more.

After evaluating the responses to the surveys, we realized we needed to strengthen our understanding of the e-waste network in Bulawayo, so it made sense to step back in order to ultimately move forward with our work. We would be unable to move ahead with any ideas until we talked to everyone that was part of the network and connected every aspect of it, ensuring there were no gaps in our knowledge. Essentially, by initially focusing on only repair technicians, we had entered the e-waste business through one door and kept moving, ignoring the other entrances and the important information we would have learned if we had used every entrance. Again, our co-design process would be improved if we were to consider every entrance, as it would allow us to decide what entry points would ultimately be best for our specific goals. This led us to reaching a new goal of attempting to uncover the entire e-waste network in Bulawayo, including where electronics come from, what happens to them in Zimbabwe, and where they go afterwards. We conducted additional interviews, but this time ensured that all stakeholders of the network were involved, including municipal bodies such as Environmental Management Agency (EMA) and Bulawayo City Council (BCC), electronics suppliers, companies like TelOne and EnviroServe, repair technicians, and waste pickers. Once we gathered more information that would inform the knowledge of the network, we were able to construct a graphical representation and ultimately provide recommendations for our project and future projects to enter the space and introduce new and valuable economic opportunities.

As we discovered throughout our project, the co-design process is never perfect. It is essential to incorporate co-design at every stage of the design process, but it is difficult to get right. This is because it is impossible to involve every single individual that will be impacted by a design. Each has their own opinions, ideas, and routines about how to go about things, so the challenge is to ensure that those who are directly involved in a design process are an accurate representation of the whole group.



Image depicting a man at the landfill with other people in the background.

Opportunities for the Future

Looking forward, we understand that there will be unpredictable but inevitable changes, similar to how our goals changed over these 7 weeks, but we still have hopes for the future. In general, the goal is to strengthen a pathway in the e-waste network that connects repair and recycling to the electronics market, indicated in Figure 3. The hope is that electronics will mostly be repaired by technicians for re-use by consumers so that less e-waste sits in landfills. When possible, informal recyclers would collect disposed electronics and sell it to repairers for spare parts, and only export them if a device is no longer of use to keep as much value as possible within the city. The next step would be to make formal recommendations for organizations, such as EMA and the BCC, on policy changes, particularly when electronics are discarded. Ensuring e-waste is segregated from regular domestic waste will make the previously mentioned pathway easier and safer. From there, we hope future projects will develop business models to formalize this pathway that will ensure income for workers, enhance the existing repair culture, reduce harmful waste, and maintain the circular economy. Another avenue for future work would be partnering with schools to implement a training program in the form of a co-op style project. This would provide students with the knowledge and skills to repair electronics and contribute to the newly implemented system.

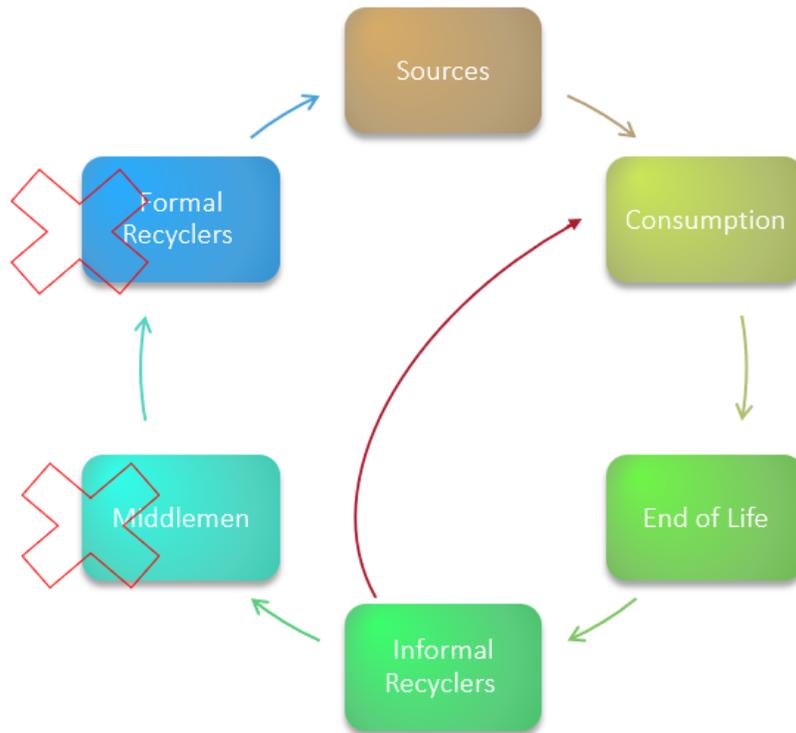


Figure 3. The proposed revisions to the current e-waste network in Bulawayo, Zimbabwe.

Because our team included students from both Zimbabwe and the U.S., our design process involved as much co-design as was possible given our situation. We believed that the best way to design was to consider the stakeholders at every step to ensure the best chance of achieving a beneficial end result. Despite the U.S. partners working remotely, we were still able to directly engage with community members, those that would be impacted by our work, through the Zimbabwean partners. Being of and in the community of the stakeholders throughout the process allowed us to stay focused on those who matter most. Going forward, we do not believe much would need to be done differently with regard to the design process. Of course, the pandemic limited the number of stakeholders we were able to involve this year, so in the future when this is no longer a factor, it would simply be crucial to continue working in diverse teams and with as many people from the community as possible.

"I should think you know, the way we repair this stuff. I should think a lot of patience is needed."

– Conway Choto

Credits and Acknowledgements

We would like to extend our deepest gratitude to the *community of Bulawayo*. These are the numerous men and women whom we interviewed and surveyed including but not limited to repair technicians, electronics suppliers, telecommunication companies, regulatory bodies, waste pickers, recyclers, and locals. These people are the reason our project has become what it is. Without the input from all those mentioned, we would never have gathered the information needed to inform our work.

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We would like to thank *Arnold Moyo* of the National University of Science and Technology in Zimbabwe for his willingness to partake in a pilot project between NUST and WPI. Without your eagerness to join us we would not have had the experiences we did and a foundation to watch our project grow from.

Thank you to *Chakanetsa Mavhunga* for always providing unique insight into our ideas and challenging us to advance our work and realize its full potential at every step.

Thank you to *Alice Clark*. Without your last minute help, our final presentation would not have been possible. We thank you for your commitment to helping us with the urgent and unforeseen issues associated with technology.

Finally, we would like to thank all the *members of our project site*, both classmates and supervisors, for their attentiveness and eagerness to always ask questions and provide input with the goal of advancing our work.

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Image depicting a man using waste and other resources to protect against toxins at the Richmond Landfill.