Access to Affordable Bicycles in Africa: Final Report

MIT D-Lab | CITE
Massachusetts Institute of Technology

Dan Frey, Megha Hegde, Maggie Hsu, Gwyn Jones, Kendra Leith, Robyn Richmond, Jonars Spielberg, and Dan Sweeney

March 2023

USAID FROM THE AMERICAN PEOPLE
MIT D-Lab designing for a more equitable world
MIT | CITE

TABLE OF CONTENTS

About USAID

The United States Agency for International Development (USAID) is a leading international development agency and a catalytic actor driving development results. The USAID Innovation, Technology, and Research Hub (ITR) (formerly the USAID Global Development Lab) works to address gaps in digital access and affordability and to advance the use of technology and advanced data analysis in development. The Research Division (ITR/R) does this by partnering within and outside of USAID (particularly with the global academic community) to promote evidence-based programming and policy making, to build human and institutional capacity within global research systems, and, ultimately, to advance USAID partner countries on their development outcomes. ITR/R works with USAID and the development community to ensure that research drives real impact through the uptake of quality data and evidence into development-relevant programs, policies, and practice.

About MIT D-Lab | CITE

MIT D-Lab works with people around the world to develop and advance collaborative approaches and practical solutions to global poverty challenges. The program's mission is pursued through an academic program of 15+ MIT courses and student research and fieldwork opportunities; research groups spanning a variety of sectors and approaches; and a group of participatory innovation programs called innovation practice.

This document is part of a series of reports produced by MIT CITE. Launched at the Massachusetts Institute of Technology (MIT) in 2012 with a consortium of MIT partners, CITE has been dedicated to developing methods for product evaluation in global development. Located at MIT D-Lab since 2017, CITE is led by an interdisciplinary team and has expanded its research focus to include studies that explore the barriers to, and enablers of, technology adoption and effective innovation processes; the outcomes of capacity building programs and technology interventions; and the contexts in which technologies and innovation processes operate. This includes a portfolio of research studies on digital financial services programs, capacity for local innovation, internet of things for agriculture, inclusive systems innovation, fairness in machine learning, and evaporative cooling technologies. CITE also develops the capacity of researchers to conduct evaluations by providing resources and tools on its methods.

This report was made possible by the support of the American People through the United States Agency for International Development (USAID) under the award AID-OAA-A-12-00095, as part of the program, the Comprehensive Initiative on Technology Evaluation (CITE). The contents of this report are the sole responsibility of MIT D-Lab and do not necessarily reflect the views of USAID or the United States Government.

Front cover photo: MIT D-Lab/Megha Hegde

Acknowledgments

The research would not have been possible with the contributions of the research teams at the University of Cape Coast in Ghana (Regina Amoako-Sakyi, Sammy Owusu, Sylvia Akakpo, Bright Ampeti, Georgina Atambila, Benedicta Konadu Kyeremeh, Clifford Korangteng, Bert Manieson, Manuel Mensah, Kwame Odame, Matilda Ohenewaa Bekoe,) the University of Malawi (Spy Munthali, Alex Dambolachepa, Sylvester Munthali, Esther Njiwa, Providence Nindi, Fazilla Tembo), and MIT (Dan Frey, Sucheta Baliga, Chisomo Billy, Megha Hegde, Maggie Hsu, Gwyn Jones, Kendra Leith, Robyn Richmond, Jonars Spielberg, Dan Sweeney); the implementing teams in Ghana at Village Bicycle Project (Ebenezer Somiah) and in Malawi at World Bicycle Relief (Chinsisi Kanyerere, Alisha Myers, Winnie Sambu, Stefano Sandfolo); and the research participants. Thank you for all of your contributions.

EXECUTIVE SUMMARY

Low-income households in low-income countries face transportation service gaps, especially in rural areas. Public transportation does not always exist and motorized transport is often unaffordable, forcing people to walk long distances to access schools, markets, healthcare and other basic services. Bicycles have the potential to fill that gap as a more affordable means of transportation. Studies have shown that bicycle use can result in health, economic and social benefits such as improved gender dynamics. In light of the benefits associated with bicycles, there are a number of organizations working to improve access to bicycles for low-income households in developing countries. While these organizations have had successes, challenges related to bicycle access and adoption persist, necessitating continued research and development.

This study, funded by USAID, seeks to understand the background, current state, and opportunities for bicycles to benefit underserved communities in Sub-Saharan Africa. Two overarching research questions guide the study:

- What factors enable or inhibit adoption of bicycles among low-income and other disadvantaged or underserved populations?
- To what extent do existing bicycle solutions perform as expected and meet users' needs?

The study consisted of three phases over a two-year period. An initial Scoping Phase included a literature review and key informant interviews. Phase I consisted of interviews with bicycle users, non-users and other stakeholders in Ghana and Malawi. Phase II included data collection through sensors, surveys, observation and in-depth interviews with bicycle-owning households in Ghana and Malawi.

In the Scoping Phase, the team sought to understand the bicycle landscape and explore challenges and opportunities to leverage bicycles in Africa. The team reviewed over 100 documents, including academic and gray literature, news, blogs and other popular media, and interviewed 30 key informant including researchers, local and international NGO staff, manufacturers, mechanics, donors, and local bicycle shop owners. Although the literature on "bicycles for development" was limited and many of the articles were dated, there were interesting findings, especially related to opportunities and challenges for bicycle use in developing countries. In addition, the key informants shared very interesting and relevant insights. Positive outcomes identified in the literature and interviews included improved gender norms, access to education, productivity and income, and efficiency and time savings. Challenges included cost, repair and maintenance of bicycles, infrastructure and government buy-in, social and gender norms, bicycle design, and lack of organizational capacity to promote bicycles. Findings from the Scoping Phase informed the two research questions, as well as the selection of two research sites for Phase I and Phase II of the project, Ghana and Malawi.

In Phase I, the goals were to identify key stakeholders, bicycle availability, use cases, bicycle ecosystem, and barriers to and enablers of bicycle use. Data were collected through observation and interviews with stakeholders in the local bicycle supply chain, such as bicycle users, non-users, producers and mechanics. In total, 182 interviews were completed: 95 in Ghana and 87 in Malawi. In each country, three geographical locations were chosen and within each one, three sites—one urban, peri-urban, and rural. The findings highlight the importance of load-carrying on bicycles, often for livelihood-related purposes and shared ownership and usage of bicycles within a household. Affordability, attitudes and perceptions of bicycles including desire to own a motorized vehicle, and design and quality issues including frequent component failure were the primary barriers for adoption, while use of bicycles for productive use, ease of travel and affordability (in comparison to motorized vehicles) were the primary enablers of bicycle use. These findings helped establish a baseline understanding of the current state of bicycle access, use, and adoption in Ghana and Malawi and informed the specific areas of focus for in-depth data collection in Phase II.

Phase I sought to understand the intra-household dynamics related to bicycle use; gather data related to bicycle usage and challenges over a longer time period; and identify challenges and opportunities related to bicycle design. This phase employed mixed methods data collection through sensors, surveys, observation and in-depth interviews. Twenty-four bicycle owning households were selected in Ghana and Malawi and engaged in the study over a five-week period through baseline interviews, endline interviews, weekly check-in surveys and bicycle-mounted sensors. Key findings uncovered in Phase II include the following:

- intra-household dynamics, especially gender dynamics, have an effect on who gets to own and use the bicycle, in most cases male heads of households;
- different members of the family use bicycles every day for different purposes;
- frequency, duration and distance of bicycle trips varied widely for the bicycles tracked and across the sample groups, with longer and more frequent trips exhibited by rural and older riders with load-carrying bicycles;
- transportation needs of a household are often not met by one bicycle;
- affordability and frequent component failure were often listed as top barriers to bicycle use among users;
- a majority of non-users were women who did not know how to ride a bicycle;
- load carrying was the most desired bicycle modification; and
- there were no significant design preferences identified based on the gender of the user.

The key findings from the study support a number of conclusions and recommendations to make bicycles more affordable to low-income households. For instance, implementers of bicycle programs may benefit from exploring diverse financing models, such as rent-to-own, payment in installments, and leasing. Funders of bicycles for development programs should offer greater

support for the import of, as well as the local design and manufacturing of, affordable and durable bicycles and spare parts in Sub-Saharan Africa. The bicycle market ecosystem can also overcome the challenge of frequent component failures and be further strengthened by training (more) small local businesses and/or users to repair bicycles.

Targeted programs that teach women and children to ride bicycles and that provide them with secure bicycle access would likely promote more equitable bicycle use. Exploring bicycle design solutions that are tailored to the needs and specificities of women is another promising avenue to investigate as a means to improve gender equity in bicycle use and access.

Given the importance of load carrying, recommendations related to bicycle design include adding gears or changing existing sprockets on bicycles to make it easier to carry a load, exploring design solutions for affordable modifications such as a low-cost carrier made from locally available materials and exploring the design and development of a heavier bicycle that is better suited for load carrying. Even though the study did not reveal gender-based design preferences, bicycles are a household asset that several individuals use, which means that developing a bicycle that can easily be adjusted to fit different rider sizes could improve bicycle access among women and children.

1. INTRODUCTION AND PROJECT BACKGROUND

As part of a USAID-funded project, Access to Affordable Bicycles, an MIT D-Lab CITE team has been conducting landscape research for bicycles to benefit underserved communities, particularly in Africa. The objectives of the study included the following:

Understand the background, current state, and opportunities for bicycles to further benefit underserved communities in Sub-Saharan Africa.

Identify the challenges in accessing and using bicycles.

Explore how to improve access to affordable bicycles.

The team explored these issues through three phases of research: scoping, Phase I, and Phase II. In the scoping study, the team conducted a literature review and conducted 30 key informant interviews with key experts in the field to understand barriers to and enablers of adoption, as well as current and future trends in the field. In Phase I, the team conducted interviews with 87 people in Malawi and 95 people in Ghana to understand transportation practices, use of bicycles, barriers to and enablers of bicycle use for users and non-users as well as other supply side actors in the field like bicycle mechanics and manufacturers. In Phase II, the team conducted interviews with 24 households in each country (two people per household- a user and non-user or less frequent user) for a total of 48 people in both countries.

2. RESEARCH METHODS

2.1. Research questions

The research questions for the project included:

- What factors enable or inhibit adoption of bicycles, especially among low-income and other disadvantaged or underserved populations?
- To what extent do existing bicycle solutions perform as expected and meet the needs of the users?

2.2. Research methods and sample

To answer these questions, the research was conducted in three phases: Scoping, Phase I, and Phase II.

Scoping (June 2020 to February 2021): In the Scoping Phase of the project, the team conducted a literature review, data review, and 30 key informant interviews with experts in the field to understand the bicycle landscape and explore challenges and opportunities to leverage bicycles in Sub-Saharan Africa. The literature review included a review of over 100 documents from academic and gray literature, news, blog posts and other popular media, as well as online searches on Google Scholar, Science Direct, Scopus, and MIT Libraries using keywords like "bicycle, international development, Africa, poverty, design, and affordable." The interviews with key informants were identified through the literature search and the D-Lab network. They included researchers, local and international NGO staff, manufacturers, mechanics, donors, and local bicycle shop owners. The team used snowball sampling to identify other potential key informants. The interviews covered topics such as gender and social dynamics, education, barriers to adoption, opportunities for bicycles to improve poverty outcomes, challenges related to bicycle access, legal and policy frameworks, current designs and solutions, gaps in solutions available, local production capacity, differences between rural/urban areas, current bicycle use, supply chain, manufacturing, and the impact of COVID-19. In the data review, the team looked at sources of existing data on bicycles and explored issues such as bicycle use, poverty/development indicators, environment, and infrastructure such as road quality in different countries in Africa.

Phase I (March 2021 to January 2022): Based on the literature and data review in the scoping study, the team identified two locations for Phase I, which included Malawi and Ghana. The goals of Phase I were to identify key stakeholders, determine bicycle availability, document bicycle users and use cases, ascertain population size and strata, complete (initial) bicycle ecosystem mapping, and identify (initial) barriers and enablers to bicycle use in each country.

In Phase I, the team collected data through observation of bicycle users as well as interviews with users, non-users/disadopters and supply-side actors such as producers and mechanics in urban, peri-urban, and rural areas in three locations across each country. The MIT team and implementing partners in Malawi and Ghana identified three sites from each of three urban, peri-

urban, and rural site types in each country, for a total of 18 sites for data collection. In Ghana, three sites of each type were sampled from each ecological region, Coastal, Forest and Savana. Similarly, in Malawi, three sites of each type were sampled from each region, North, Central and South. Table 1 below details the sites by type and location.

Location category	Malawi			Ghana		
Region (administrative)	North	Central	South	Central	Bono East/Ashanti	Northern
Region (ecological)	—	—	—	Coastal	Forest	Savana
District	Mzimba	Lilongwe	Blantyre	—	—	—
Urban site	Mzuzu	Lilongwe	Blantyre	Abura	Kintampo	Tamale
Peri-urban site	Ewkendeni	Mitundu	Lunzu	Ankaful	Dumsu	Fooshegu
Rural site	Ekwaiweni	Chiseka	Lirangwe	Ebukrom	Apaah	Sang

Table 1: Locations for Phase I

The team spent time in different locations (urban, peri-urban, and rural) to observe a number of factors including location, number of riders, gender, age, safety precautions, type of bicycle, wear and tear, modifications, traffic conditions, load carrying, interactions with other people, and behavioral observations.

In the interviews with users and non-users, the team covered topics such as transportation practices, bicycle and use, barriers to and enablers of bicycle use and demographics. With the supply side actors, the team uncovered information related to their role and organizational information, the transportation landscape, bicycle use, barriers to and enablers of bicycle use, demographics, and specific relevant questions for individual supply side actors. The team completed 95 interviews in Ghana and 87 in Malawi. The interviewees were identified through purposive sampling and convenience sampling.

The participants included the following groups in Ghana and Malawi:

Ghana	Peri-urban	Rural	Urban	Total
Dis-adopter	5	10	11	26
Non-User	7	1	2	10
User	12	18	17	47
Provider	3	2	7	12
	27	31	37	95
Malawi				
Dis-adopter	1	3	3	7
Non-User	5	9	7	21
User	11	18	13	42
Provider	6	4	5	15
Enabler			2	2
	23	34	30	87

Table 2: Sample for Phase I

Phase II (February to September 2022): The goals of Phase II were to identify intra-household dynamics as they relate to bicycle use, gather data over a longer period of time on the challenges people face when riding bicycles and bicycle use, as well as identify design challenges and opportunities.

In Phase II, the team returned to Ghana and Malawi and conducted pre-screen surveys to identify potential participants. Once the team selected the participants, they conducted in-depth interviews with users and non-users and weekly check-ins with users and gathered information through observation and sensors. The focus of this part of the study was in rural areas, where there was likely the greatest need and opportunity to address the needs of the bicycle users.

Pre-screen Survey: One person from a household was surveyed on questions regarding household transportation use, barriers, and demographics (age, sex, wealth/poverty probability index). COVID screening questions were also asked in accordance with requirements from MIT's IRB (COUHES). This initial survey lasted about ten minutes and was completed with 50-75 individuals in each country. From this pool of potential candidate households, researchers identified the final households for inclusion in data collection based on selection criteria such as having a bicycle within the household, presence of users/non-user, and poverty probability index.

Interviews and Observation: Two rounds of interviews were conducted with users, one in the beginning and one at the end of the data collection period, with a four-week gap in between (June to July 2022). In the first round of interviews, topics covered included: bicycle ownership, use and access, and current transportation practices. In the second round of interviews, the interviews included the following topics: challenges related to bicycle use (in the last month), barriers and enablers of bicycle use, and feedback on bicycle design. A bicycle riding demonstration by users was also completed in order to observe any design-related challenges. For the non-users/less frequent users, the team conducted interviews at the end of study period that covered topics such as transportation practices and barriers to and enablers of bicycle use.

Weekly check-ins: Once a week for three weeks, quick check-ins were conducted with users regarding their bicycle use and any challenges encountered in the previous week.

Sensors: For all consenting bicycle users, field researchers installed a compact, battery-powered sensor that electronically measured distance and time traveled to objectively measure bicycle usage over time. The sensors were installed on 20 bicycles in each country during the first round of interviews and removed during the second round of interviews.

The sample consisted of 24 households per country, split evenly between two rural sites in the northern and southern regions. Within each household, 2 individuals—one bicycle user and one non-user or less frequent user—were selected as research subjects for a total of 48 subjects in each country.

Ethical approval

For all phases of the research, the team acquired the appropriate ethical approvals from MIT, the University of Malawi, and the University of Cape Coast to conduct the research. In all cases, participants were asked to consent to participate in the study and for data collection that occurred in person, Covid protocols were followed.

2.3. Limitations

This study is not without its limitations. In the scoping study, the number of interviews was small and the interviewees were identified through our immediate network, the literature, and snowball sampling, which means that the sample could be biased. In Phase I, the sample was relatively small and the sampling included some convenience sampling and some purposive sampling. In addition, Phase I was non-longitudinal, but rather a point in time and we emphasized breadth over depth in terms of topics. In Phase II, the sample was also relatively small and focused more on depth rather than breadth. Although this study took place over time for the users, it still only covered one month of time, which could limit the findings. In addition, issues with sensors (installation, charging, data transmission) meant that we were unable to collect as full of a dataset on usage as we would have liked. Finally, in Phase II, some participants were less willing to spend time answering questions as the duration of the study progressed, so this may have resulted in lower-quality and reduced accuracy in the results.

3. RESULTS

3.1. Findings from Scoping Phase

In the initial Scoping Phase of the study, the team conducted a literature review and 30 key informant interviews. This section outlines the key findings from those sources.

Summary of findings from the Scoping Phase:

Although the literature on bicycles is limited and some of the sources are older, the team was able to identify a number of opportunities and challenges related to bicycles. Positive outcomes of bicycle usage include improved gender norms, improved access to education, increased productivity and income, and improved efficiency and time savings. Even though there are several benefits of using bicycles, there are also a variety of challenges and barriers to adoption, which include, but are not limited to, high costs, unfavorable government regulations, lack of infrastructure, restrictive social and gender norms, unsuitable bicycle design, lack of access to spare parts, poor aftermarket service, and lack of organizational capacity to promote bicycles.

Details of key findings:

Bicycle production, exports, and imports

Worldwide, over 100 million bicycles are produced each year (International Bicycle Fund, 2003). To place this number in context, this number is more than double the number of automobiles manufactured in a typical year.

The most common bicycle type in Africa is the "roadster" type, which is an affordable and durable utility bicycle imported predominantly from India, China, and Taiwan. The region imports only a small percentage of bicycles globally, though imports far exceed exports as local manufacturing remains low. From 2000 to 2018, Sub-Saharan Africa (SSA) represented about 1.5% to 2% of the global imports and in 2018 in SSA, bicycle imports represented about $120 million (United Nations, 2019). In terms of exports, in 2018, SSA represented only 0.1% to 0.15% of total bicycle exports globally (United Nations, 2019).

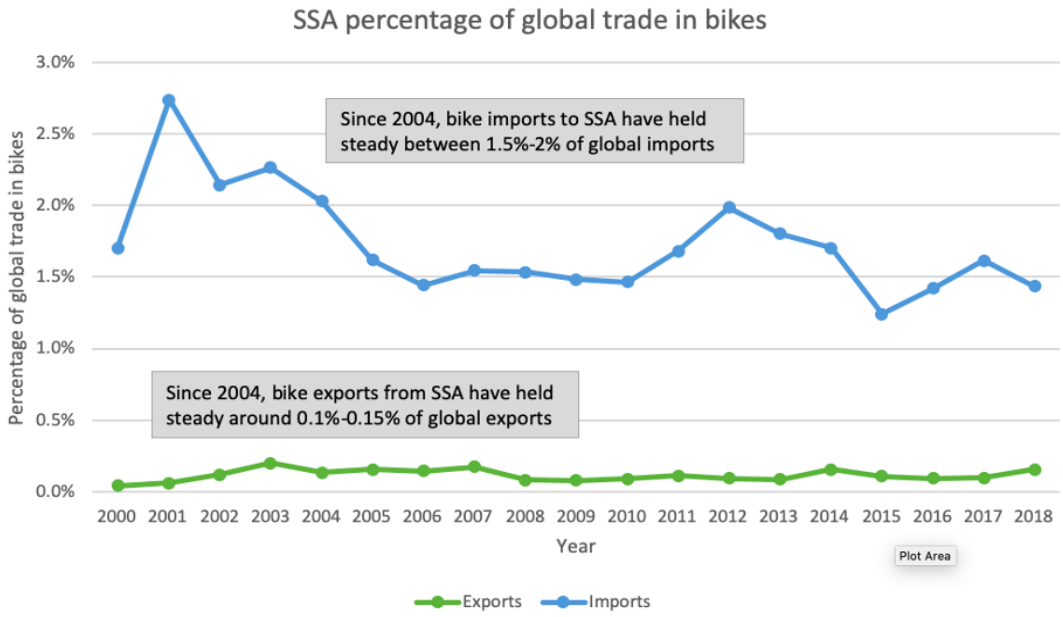


Figure 1: Sub-Saharan Africa (SSA) percentage of global trade in bikes; source: United Nations Comtrade, 2019

Dependence on imported bicycles and limited local manufacturing capacity

Although bicycles have been produced on the continent, African countries remain largely dependent on the supply of inexpensive imported or donated bicycles supported by informal maintenance and repair networks. A survey in rural Kenya reported that approximately 65% of bicycles were purchased second-hand (Baker, 2018). The supply of second-hand bicycles through philanthropic and development interventions has often resulted in a mismatch between

the mobility needs of Africans and intended uses of low-end, discarded bicycles. Communities, with the support of local mechanics, often subscribe to and adapt, or reject, the bicycle design to meet their diverse needs (Baker, 2019, 2020).

Opportunities to leverage bikes

Based on the literature and key informant interviews, bicycle usage has resulted in a number of positive outcomes, including improved gender norms, increased access to education, increased productivity and income, and time savings.

Improved gender norms

In interventions that focused on bicycle access to women and girls, it was reported that access to bicycles improved gender norms in the community and led to female empowerment (Fiala et al., 2018; Muralidharan & Prakash, 2017; two respondents, personal communication, various dates August to September 2020). This finding has been reported in several newspaper articles and blogs as well (for example, in Iran, Saudi Arabia, and Tajikistan). Studies have shown that women often use bicycles for productive purposes such as taking advantage of income-generating opportunities and improving access to education for their children (One respondent, personal communication, August 26, 2020), as well as for social purposes such as shopping, recreation, and visiting family and friends more so than for economic purposes (L. Song et al., 2019). There is also some evidence that bicycles can help women and girls save time, opening up possibilities for additional activities (Two respondents, personal communication, various dates August to September 2020).

Improved access to education

There is also evidence that bicycles have a positive impact on educational outcomes. Studies have found that bicycles are a cost-effective way to increase access to education by reducing travel time in rural areas (Fiala et al., 2018; Girls Not Brides & Janaki Women Awareness Society, 2017; Muralidharan & Prakash, 2017; Räber, 2014; L. K. Song, 2003). In addition, studies demonstrate evidence of increased enrollment, decreased dropout rates, better performance in tests, decreased absenteeism, and improved punctuality. Girls with access to bicycles and education have also reported feeling more empowered (Fiala et al., 2018; Girls Not Brides & Janaki Women Awareness Society, 2017; Muralidharan & Prakash, 2017; Savage, 2020). Some of the key informant interviews also supported this evidence (Two respondents, personal communication, various dates August to September 2020). Interventions in Sierra Leone have shown benefits of using bikes to access school. This also led to improvements in grades and attendance. Although there is some evidence of bicycles having a positive impact on education, one respondent indicated there is also a need for more research (personal communication, August 19, 2020).

However, several studies have indicated that in places where bicycle programs were not combined with targeted educational programs, children used the bikes for recreational purposes and to run errands (Amoako-Sakyi & Owusu, 2012; Fiala et al., 2018; Muralidharan & Prakash, 2017; L. K. Song, 2003), rather than using them to access school. This indicates that the bicycles may need to be part of a larger program to ensure lasting social change.

Increased productivity and income

There are also a number of documented benefits related to improving productivity and increasing income (Raber, 2014; Shirazi, 2020; Four respondents, personal communication, various dates August to September 2020). Bicycle use for income-generating activities is common among urban and rural riders (e.g. goods and materials delivery, courier, passenger transport, knife sharpening) (Shirazi, 2020). There is evidence that bicycles can increase agricultural productivity in rural areas (Hine & Rutter, 2000). For a household engaged in agriculture, one study estimated that farmers would gain 3,000 additional working hours if bicycles were available for community members (Peier, 2015). In addition, bicycles can also increase access to agricultural extension agents and valuable agricultural information, as demonstrated in Malawi (World Bicycle Relief, 2019c). Bicycles can also be used to create a passenger and small goods carrier service, generating additional income, such as in Kampala/Uganda (Bryceson et al., 2003). Some interventions targeting women have shown improvements in income because bikes enable women to go to multiple markets for economic purposes, which was not possible previously. (One respondent, personal communication, August 26, 2020). Another study in Kenya found that for female business groups, women with bicycles experienced more positive business outcomes as compared to a control group that did not receive bikes (World Bicycle Relief, 2019b). Thus, there is evidence of potential benefits related to productivity and income.

Improved efficiency and time savings

There are many reasons why the modern bicycle design is so popular. From an energy efficiency perspective, bicycles rank first among traveling animals and machines with the average rider requiring just 0.15 calorie per kg per kilometer, one-fifth of the average walking human (0.75 calorie per kg per kilometer), and one-fortieth of an automobile (7 calorie per kg per kilometer) (Wilson, 1973).

Given that riding a bicycle comes with additional efficiency, there are associated benefits of time savings, as people can accomplish tasks more efficiently including carrying more goods a farther distance at a quicker pace. This means that the users can increase the number and diversity of activities, which can lead to increases in both earnings and savings (Peier, 2015).

Access to healthcare

Bicycles can also increase access to healthcare services. Bicycles are a primary way for low-income households to access clinics (One respondent, personal communication, August to September 2020). In addition, greater presence of bicycle ambulances has helped enlarge healthcare coverage to previously non- and underserved communities (Two respondents, personal communication). Finally, bicycles have been used to provide targeted care services to people living with HIV/AIDS in isolated areas (One respondent, personal communication, August to September 2020).

Bicycle organizations

Given the potential benefits of using bicycles, there are a number of organizations working to improve access to bicycles, including Bikes for the World, Wheels 4 Life, Bikes Not Bombs, Village Bicycle Project, and Velafrica, among others in Sub-Saharan Africa. Many of these organizations ship bicycles from the US or Europe. In an attempt to overcome challenges with second-hand bicycles, several non-profit initiatives filter only bicycles that are in good condition and provide tailored maintenance training and tools to local mechanics and riders. The Village Bicycle Project in West Africa is an example of a successful organization that has provided access and maintenance support in low-income communities totaling more than 100,000 second-hand bicycles since 1999 (Appropriate Technology, 2017).

Other initiatives by startup manufacturers have introduced a “made in Africa for African needs” bicycle. World Bicycle Relief’s Buffalo Bicycle is designed for rugged use and easy repair, with coaster brakes, heavy-gauge steel tubing and spokes, and a cargo carrier capacity of 100kg. Buffalo Bicycles are assembled at workshops in Africa (Zambia, Zimbabwe, Kenya, and Malawi (World Bicycle Relief, 2019a)) from parts manufactured in Asia, and distributed across entrepreneur-technician and NGO networks across Africa. Approximately 500,000 bicycles have been distributed through Buffalo Bicycles and other WBR initiatives (World Bicycle Relief, 2019a). Similarly, the Institute for Transportation and Development Policy (ITDP) and Afribike in South Africa partnered to develop the “Africa Bike”, a $65 bicycle designed for durability, ease-of-maintenance and appealing aesthetics compared to the more common “Black Roadster” found across Africa (White & Budnick, 2001). Accurate numbers for the penetration of “made in Africa” bicycles in the African market have not been located; however, they are likely a small fraction of overall supply.

With a shortage of suitable steel sheet and tube material, and large-scale manufacturing capacity, several designers are constructing bicycle frames from locally available materials, including bamboo. Bamboo has a similar tensile strength compared to steel, but is 20%-30% lighter and requires less specialized tools to cut, form and join (Ukoba et al., 2011). However, joining bamboo members is challenging and often requires specialized adhesives that add to the cost, complexity and mass of bamboo frames. Therefore, imported steel frames distributed through well-

established supply chains are more common, including in African countries (One respondent, personal communication, December 14, 2022). Booomers Bamboo Bikes and Ghana Bamboo Bikes are producing bicycle frames locally in Ghana from bamboo and importing the remaining components. While small-scale, local manufacturing of bamboo bicycles is achievable with low-investment, due to the low volumes, they are unable to achieve the scale and production cost of large, Asian bicycle suppliers (One respondent, personal communication, August to September 2020).

Challenges to bicycle use

Despite the potential benefits of bicycles, there are also challenges that limit access and use. Literature and key informant interviews revealed that, high costs, unfavorable government regulations, lack of infrastructure, restrictive social and gender norms, unsuitable bicycle design, lack of access to spare parts, poor aftermarket service, and lack of organizational capacity to promote bicycles are some of the main barriers to bicycle use.

High cost and lack of access to credit to pay for bicycles

One of the biggest barriers is the upfront cost of a bicycle (Five respondents, personal communication, various dates August to September 2020). Bicycles range widely in price based on type, material, and country and can be as low as around $40 for ones imported from India, and as high as $150 for a Buffalo Bicycle (England & Manson, 2012). Community members often have limited income and purchasing power for this type of product, which means that financing is often required (Ardizzi, 2018). However, access to credit is also a challenge (Peier, 2015), although two key informants indicated that customers prefer payment plans (personal communication, various dates August to September 2020). These two issues combined often make bicycles unaffordable to many community members in low- and middle-income countries.

High transportation costs, tariffs, and taxes

Transportation and shipping costs associated with bicycles can often be high, making import of bicycles difficult, especially for landlocked countries (Ardizzi, 2018; four respondents, personal communication, various dates August to September 2020). This can be true even when the bicycles are donated (One respondent, personal communication, August 28, 2020). Once the bicycles arrive in the country, they may also be subject to high taxes and import tariffs. In places like Ethiopia, Ghana, and Tanzania import taxes can be as high as 200% to 500%, making it very expensive to import bicycles (Sieber, 1999). There can also be a fair amount of uncertainty related to the import process (Three respondents, personal communication, various dates August to September 2020).

Government regulations and policies

Oftentimes, government regulations on imported bicycles can be strict (Gauthier & Hook, 2005; Sieber, 1999). In East Africa, one informant indicated that it has been harder to ship bicycles to the region due to stricter and evolving regulations on importing used goods, as governments do not want second-hand goods arriving in their countries (One respondent, personal communication, August 19, 2020).

In terms of mobility and transportation policy, bicycles generally receive little attention or consideration, at both the global and national level. Mobility is not considered a top priority on the international development agenda (Pojani & Stead, 2015). At the national level, governments tend to promote mobility and transportation policies that favor motorized vehicles, especially cars, to the point where other modes of mobility operate within a "policy and planning vacuum" (Sietchiping et al., 2012, p. 185). Broadly speaking, the car is seen as a "modern" technology, whereas the bicycle is often seen as a "backward" technology, one associated with low-income or rural communities (Pojani & Stead, 2015; one respondent, personal communication, August 19, 2020).

Social and gender norms can limit bicycle use and adoption

Social norms and preferences also have an effect on adoption. People often prefer motorized vehicles and often think of bicycles as a "poor person's" transportation, which means that people may be less likely to adopt the bicycle (Nkurunziza et al., 2012). Urban dwellers are more likely to forego bicycle ownership for the convenience of using public transportation or purchasing a motorized vehicle (Amos, 2008; One respondent, personal communication, September 3, 2020).

Women are often responsible for e.g. gathering fuel, water and crop harvest, activities for which a bicycle could be helpful and at the same time, gender issues and social norms also prevent women from adopting bicycles (Acheampong & Siiba, 2018; Calvo, 1994; Porter, 2014). For instance, there is the belief that women may lose virginity if they ride a bicycle (One respondent, personal communication, August 19, 2020) or girls might be spoiled or independent if given a bicycle (One respondent, personal communication, August 25, 2020). Strategies for addressing these difficulties have included engaging local leaders and community members broadly, providing bicycles to boys and men in addition to girls and women, providing bicycles at scale to encourage mass participation, and repeated sensitization and training programs (Two respondents personal communication, various dates August to September 2020).

This is compounded by the fact that it may be challenging for women to access bicycles (Five respondents, personal communication, various dates August to September 2020) and women may lack knowledge on how to ride bicycles (Two respondents, personal communication, various dates August to September 2020). Finally, men may be more likely to use bicycles (Adom-Asamoah, et al., 2020; Calvo,1994; Song et al., 2019).

Difficult terrain and weather and inadequate infrastructure

Terrain, weather, and infrastructure also present a challenge for using bicycles. Mountainous or hilly regions, unpaved and muddy roads during the rainy season make it difficult for bicycle use (McSweeney et al., 2020; Five respondents, personal communication, various dates August to September 2020).

Topographical and weather challenges combined with inadequate infrastructure can make it even more difficult for users to adopt and continue to use bicycles (Hine & Rutter, 2000; McSweeney et al., 2020; three respondents, personal communication, various dates August to September 2020). In urban areas, infrastructure issues such as lack of bicycle lanes and heavy traffic prevent people from using bicycles (Amoako-Sakyi & Owusu, 2012; Sietchiping et al., 2012).

In addition, many of the bicycles currently available are poor quality and not rugged enough for rural roads (Three respondents, personal communication, various dates August to September 2020) and areas where there is inadequate infrastructure (Hamilton, 2012; The Economist, 2008).

Design of bikes often not suited to use case or user

It has been reported that the bicycle may not be designed for appropriate use cases, such as load carrying capacity (Peier, 2015). In addition, many of the bikes are designed for male bodies (Calvo, 1994; L. Song et al., 2019) and clothing, which means that women may face discomfort and be less likely to adopt it.

Safety concerns

There are also safety concerns related to accidents with motorized vehicles, a lack of helmets, poor maintenance, and reliance on informal providers for repair (Bryceson et al., 2003). Safety concerns are also linked to gender, where women fear harassment and crime, or limit their bicycle use to times (daylight hours) and places (closer to home) they feel safer (L. Song et al., 2019).

Spare parts and aftermarket services may be limited and repair costs can be expensive

There is also evidence that spare parts to repair bikes are not readily available and the after-market support is limited and expensive, which could lead to disadoption (World Bicycle Relief, 2019b, Mahapa, 2003). This was also confirmed in interviews (Two respondents, personal communication, various dates August to September 2020). One informant further noted that bicycles are typically sourced from one or two primary countries, which limits the kinds of spare parts that are available locally (Personal communication, August 7, 2020).

Lack of organizational capacity

There is a shortage of organizational capacity to implement and evaluate bike programs (One respondent, personal communication, August 28, 2020). Most organizations have weak capacity for monitoring, evaluation, and learning and therefore have little insight on what programs work,

how, and why (Two respondents, personal communication, various dates August to September 2020). The fact that many organizations rely on volunteers and on managing numerous partner relationships further adds to the logistical complexity of providing bicycles (One respondent, personal communication, August 28, 2020). However, organizations are beginning to think more critically and more long-term regarding programming. For example, World Bicycle Relief and Bikes Not Bombs have both completed strategic planning processes in order to guide decision-making and to allocate organizational resources based on strategic priorities (Two respondents, personal communication, various dates August to September 2020).

Conclusion of findings from literature review and key informant interviews

Bicycles are an efficient way of getting around and there are a number of benefits of using bicycles, that include but are not limited to, improved gender norms, access to education, and income-generating opportunities, as well as time savings. However, there are also a variety of challenges and factors that limit adoption of bicycles, such as high costs, unfavorable government regulations, lack of infrastructure, restrictive social and gender norms, unsuitable bicycle design, lack of access to spare parts, poor aftermarket service, and lack of organizational capacity to promote bicycles. The team also discovered that currently, there is limited literature on bicycles for development. Hence, as part of Phase I of the study, the team identified critical research questions and selected specific geographic locations for primary data collection to answer those questions. Research findings from Phase I are discussed in the sections below.

A bicycle mechanic repairing a bicycle in Zomba, Malawi. Photo: MIT D-Lab/Megha Hegde

3.2. Findings from Phase I

In Phase I, the teams in Ghana and Malawi conducted interviews with bicycle users, non-users, and supply side actors. The goals of Phase I were to identify key stakeholders, determine bicycle availability, document bicycle users and use cases, ascertain population size and strata, complete (initial) bicycle ecosystem mapping, and identify (initial) barriers and enablers to bicycle use in each country.

Demographics

From the total participants in Phase I, the male to female ratio was around 3:1, so it is possible that the data is biased by primarily male interviews. This ratio was consistent in both Malawi and Ghana. See Table 3 below for the complete gender breakdown.

	Male	Female	Total
Ghana	61	15	76
Malawi	50	20	70
Grand Total	111	35	146

Table 3: Gender breakdown for demand-side actors from Phase I

There is a wide distribution of ages of respondents in both countries, with the largest proportion of adults (ages 25-39), and the smallest proportion of elderly (60 and above).

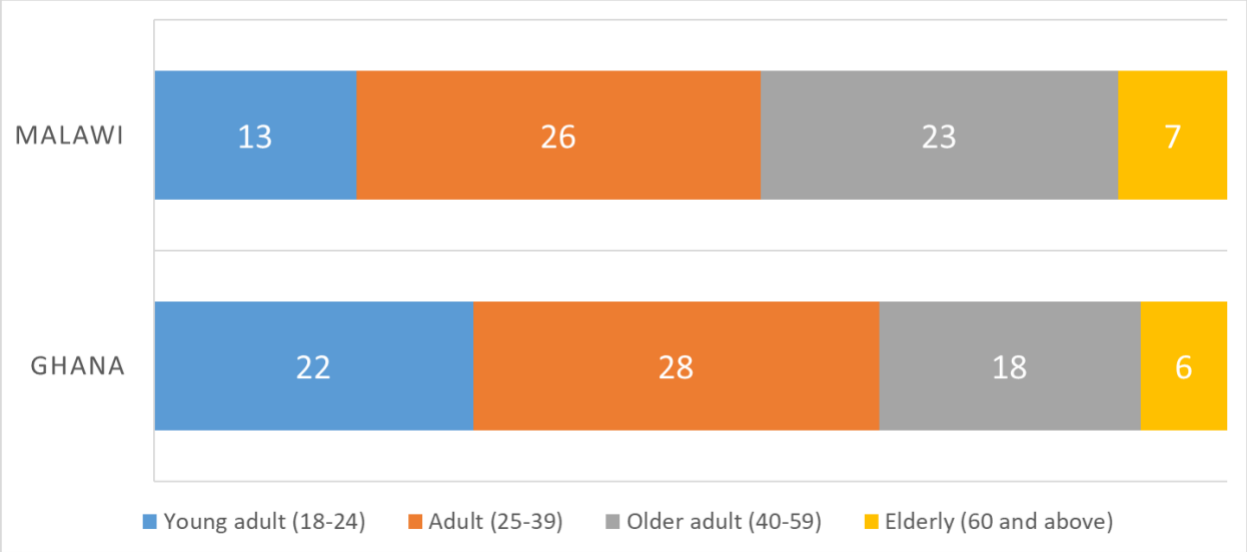


Figure 2: Age breakdown for Phase I

As shown in the graph below, there is a much greater proportion of respondents likely living in poverty interviewed in Malawi than were interviewed in Ghana. However, this did not seem to skew data related to affordability, which will be discussed in the barriers section.

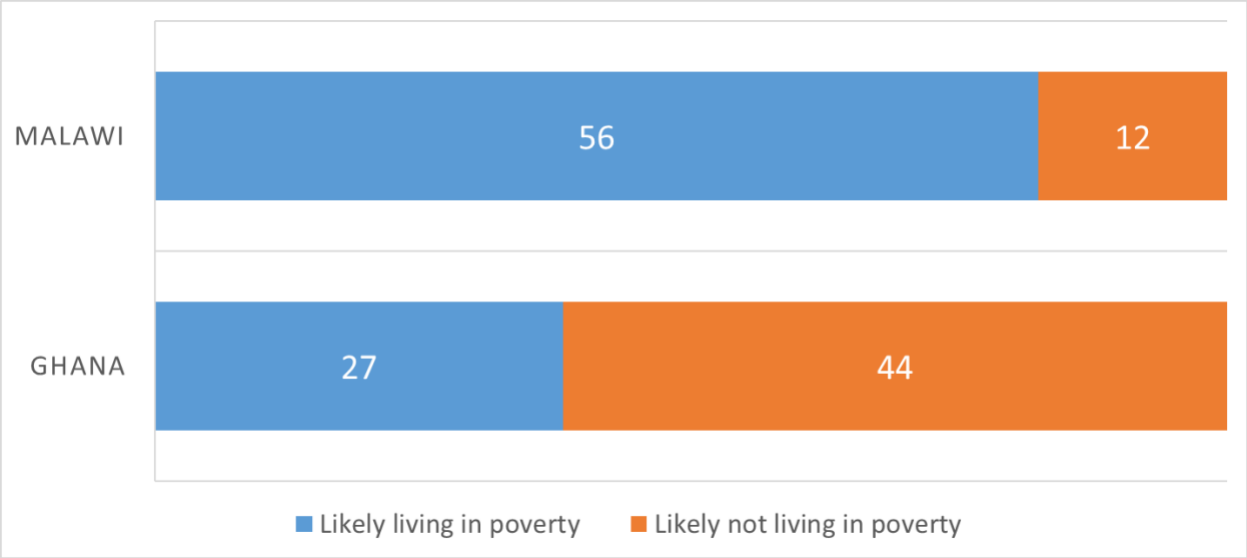


Figure 3: Likely poverty levels from Phase I

Transportation practices

Changes over time

Research implementation partners in each country asked supply-side actors about how bicycle use has changed over the past decade, during the pandemic, and how they predict it will change over the next decade. Respondents in each country reported different observed changes over the past decade. Respondents in urban areas of Ghana reported more frequently that prices of bicycles and parts and usage of motorcycles has increased over the last decade. Respondents from all three site types in Ghana observed that usage of bicycles has increased over the last decade, but decreased usage was also reported in both urban and rural areas. This phenomenon also occurred in Malawi, where urban and peri-urban respondents observed increased usage of bicycles, but decreased usage of bicycles in all site types, especially rural. As you can see, opinions on the changing landscape of bicycle use vary in both countries, and are dependent on individual observations and situations. Urban respondents in Malawi also reported that new bicycle routes, additional pathways and infrastructure for bicycles has increased over the past ten years, as well as increased usage of bicycles for load-carrying. In Malawi, increased usage of motorcycles was reported across all site types, but especially in urban and rural areas.

Changes during the pandemic observed by supply-side actors were more consistent across the two countries. Both Ghana and Malawi saw increased bicycle and part prices, decrease in

income, and decreased usage of bicycles. Ghanian suppliers also noted the decreased availability of bicycle parts. Some respondents indicated that there were no changes due to the pandemic.

Predicted changes reported were also consistent across both countries. There was a mix of respondents predicting increased bicycle usage and decreased bicycle usage. In both countries, respondents predict increased use of motorcycles, in urban Ghana and especially rural Malawi. It will be interesting to see what the long-term impact of the pandemic is on bicycle usage, and what factors affect this most significantly, since many supply-side actors disagree.

Transportation modes and preferences

When examining the reported transportation modes for Malawi and Ghana, respondents mentioned bicycles most frequently, followed closely by cars and taxis, walking, and motorcycles.

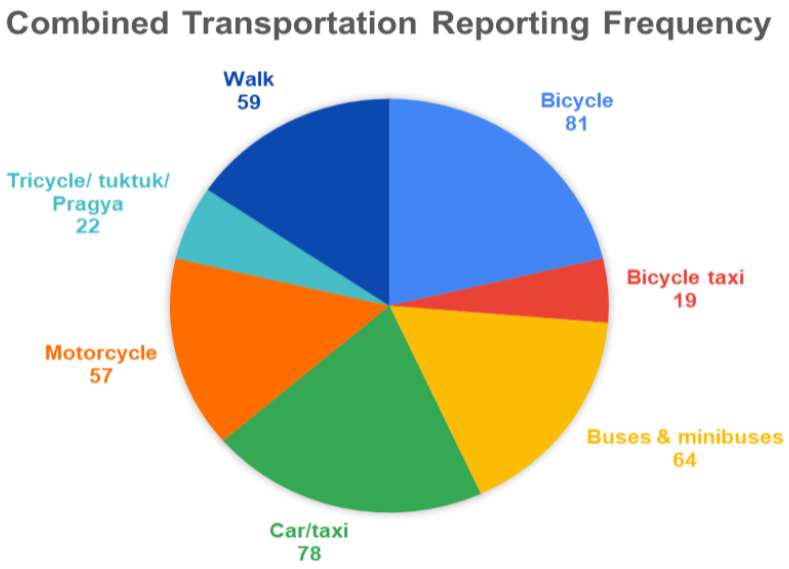


Figure 4: Combined transportation reporting frequency for Ghana and Malawi

Reported transportation modes used in Ghana, from most to least reported, are car or taxi, bicycle, and motorcycle, followed by tricycle/pragya/tuktuk and walking. In Malawi, bicycle and bicycle taxi usage was reported more often, followed by minibus, car and taxi, motorcycle, and walking. In both countries, bicycles are the preferred mode of transportation as reported by over 40% of respondents in Ghana and over 60% in Malawi because of the ease access to bicycles and affordability of bicycles compared to other means of transportation. Higher bicycle usage and preference in Malawi aligns well with the evidence of stronger support network infrastructure for bicycle usage compared with Ghana. However, lower usage rates in Ghana may be due to the higher proportion of respondents likely not living in poverty interviewed in this country; higher-income residents presumably have increased opportunity to use other, more expensive modes of transportation. In Malawi, preference for bicycles correlated with lower income levels, especially in rural areas.

Bicycle use and purpose

Figure 5 below shows the distribution and variety of bicycle use purposes. In Malawi, the highest reported bicycle use is for bicycle taxi business, followed by business and work-related travel. In Ghana, work-related travel was also reported as one of the primary uses for the bicycle. In both countries, about 20% reported using a bicycle to go to the farm. This shows that bicycle usage is closely linked to economic activity for individuals, and that improvements to bicycle accessibility and infrastructure could have a positive impact on poverty in both of these countries.

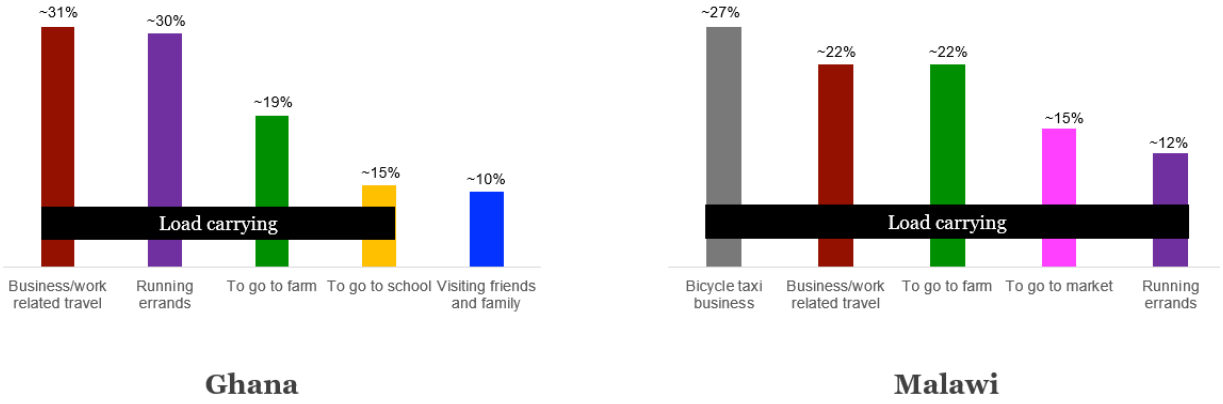


Figure 5: Bicycle use in Ghana and Malawi

Even if not conveyed explicitly, load-carrying came up frequently in these two countries. Respondents reported increased usage of bicycles during harvest season, implying the increased use of bicycles for going to farm and for load-carrying. As you can see, capacity for carrying people, goods, and agricultural products (among others), is an important aspect of bicycle usage in both of these countries, and indicates a user need that may not be met by all bicycle designs used in this context.

Bicycle access

Ownership and shared usage

In both Malawi and Ghana, the majority of bicycle users reported that they own and share their bicycle, among friends and family within and outside their immediate household.

Most bicycle owners reported purchasing their bicycle by themselves, with around half in each country purchasing formally from a shop and half purchasing informally from someone.

Bicycle brands

The primary bicycle brand reported in Ghana is Phoenix. There was also some reporting of locally produced Boomers Bamboo and Ghana Bamboo bicycles. In Malawi, there is a more varied set

of bicycle brands because more used bicycles are imported here than in Ghana. Humber and Hunter make up the primary brands, but others include Halo, Neram, Hero, Lion, Buffalo, Avon, and Raja.

Barriers and enablers

The team also asked respondents about barriers to and enablers of bicycle use. Affordability and personal attitudes and perceptions accounted for the majority of both barriers and enablers identified during data collection for Phase I. Additional barriers related to design and quality also made up a significant portion of barriers identified. Personal riding experience presented another set of enablers that contributed to bicycle adoption. These barriers and enablers will be analyzed in more depth in the sections below.

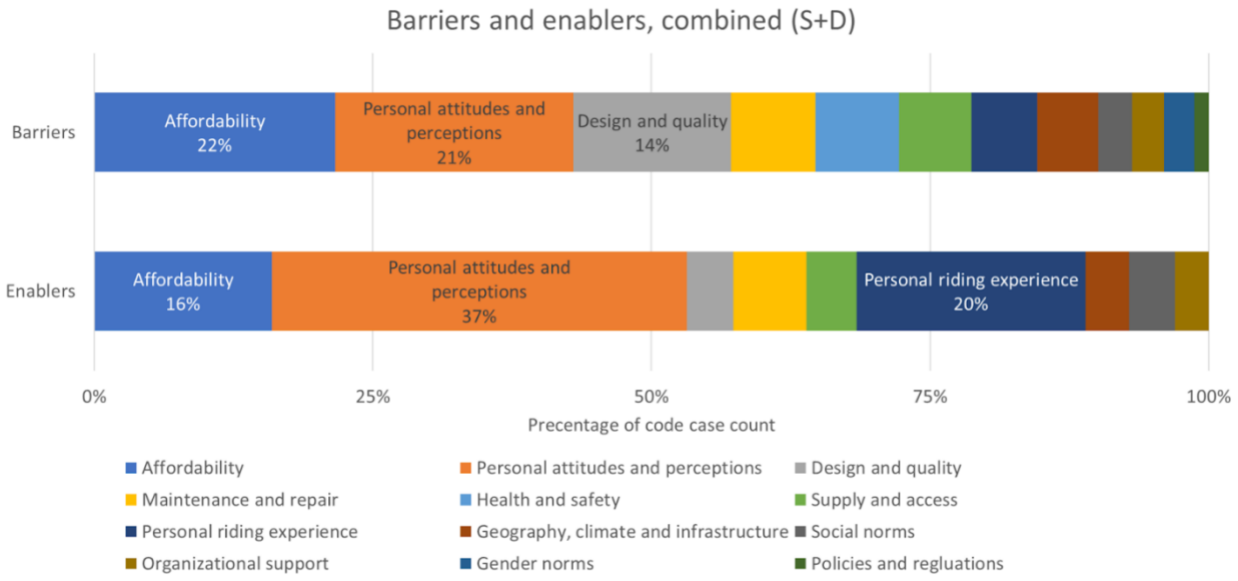


Figure 6: Barriers and enablers

Barriers

The total case count for high-level barriers in Phase I is 1928 for both Ghana and Malawi. The primary barriers to adoption of bicycles are affordability (case count 417), perceptions and attitudes (case count 412), followed by design and quality (case count 273). These barriers were identified consistently across both Ghana and Malawi. Respondents in both Ghana and Malawi consistently reported affordability barriers, despite the mismatched proportion of respondents likely living in poverty between the two countries. Gender and social norms are also barriers to adoption, but these were reported with a much lower frequency than expected (52 and 58 respectively). This may be due to the low number of women sampled in this phase.

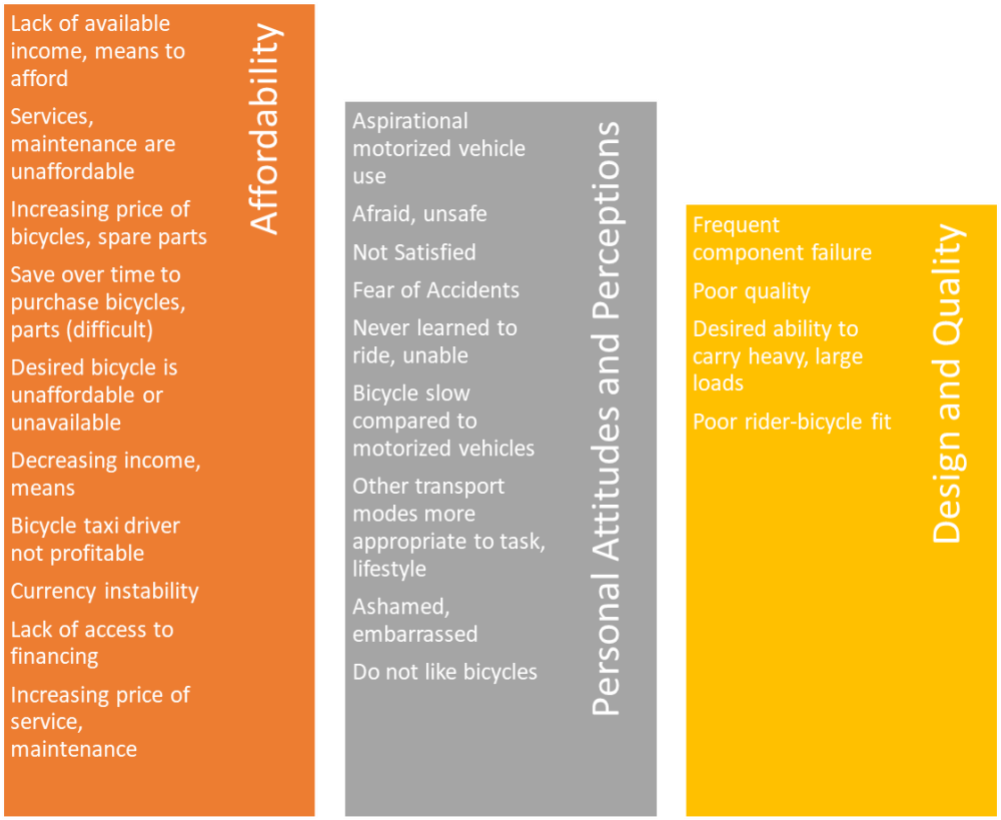


Figure 7: Top barriers

Each of the top barriers is broken down into sub-codes, which are listed in Figure 7 above. Lack of available income and means to afford made up 50.4% of the affordability cases reported. Additional affordability barriers include unaffordable maintenance and services as well as increasingly expensive bicycles and parts. Supply-side interviews indicated that the pandemic has reduced supply and increased prices, resulting in less business for mechanics. For example, school shut-downs reduced bicycle usage in schoolchildren, therefore reducing business for repairmen and bicycle mechanics.

In Ghana, rural areas are more heavily affected by affordability barriers; 47% of the total affordability cases were reported by respondents in rural sites. Households likely living in poverty in rural areas of Ghana reported lack of means and income to afford bicycles, as well as increasing cost of bicycles and bicycle parts more frequently than other site types. In Malawi, 40% of total affordability cases were reported from peri-urban sites. These affordability barriers include difficulty in saving for a bicycle, difficulty in producing profit from bicycle taxi work, and were more frequently reported by peri-urban households likely living in poverty.

Perceptions and attitudes also present an important set of barriers to bicycle adoption in Malawi and Ghana. Negative feelings and perceptions are more common among households living in

poverty. One bicycle user in Ghana explained that riders are not treated well, that “If you are riding a bicycle, it’s like you are nobody…You are just a poor person…they don’t value you.” In Ghana, negative feelings and perceptions emerged more frequently in rural sites, whereas this emerged more often from peri-urban sites in Malawi.

Aspirational motorized vehicle use was the most commonly reported barrier in this category in both countries, making up 24.4% of perceptions and attitudes barrier case counts. In Ghana, 62% of aspirational motorized vehicle use cases emerged in urban sites from respondents likely living in poverty, while in Malawi this barrier was more common in peri-urban areas, accounting for 79% of the code cases. One rider in Malawi explained, “my desire is to move from the stage of using bicycles to maybe motorcycles and that is why I am not satisfied with a bicycle.”

Additional barriers related to perceptions and attitudes include feelings of being afraid or unsafe, inability to ride or never learned to ride a bicycle, and fear of accidents. Feelings of being afraid or unsafe account for 16.5% of perceptions and attitudes barrier cases, and are slightly more common in urban and peri-urban areas for both countries. Similarly, fear of accidents (10.7% of perceptions and attitudes) was generally more common in urban areas. In Malawi, the majority of these reports, around 69%, came from urban areas, with almost no cases from rural areas. However, in Ghana, this barrier affects all geographical site types similarly, but is slightly more common in both urban and rural areas. Another barrier to adoption of bicycles people experience is the inability to ride or having never learned to ride a bicycle. This is slightly more common in peri-urban and rural areas for both countries.

An overwhelming majority (90%) of design and quality issues are from frequent component failure. Failed tires and tubes resulting from punctures are the most frequently mentioned components in both countries, making up 35% and 15% of total component failures reported in Phase I. In addition, bicycle chains, along with brakes in Ghana and spokes in Malawi, make up the remaining primary component failures. In Ghana, component failure affects urban sites more heavily, making up 57% of the case count for this barrier. In contrast, in Malawi, this barrier is slightly more common in peri-urban and rural sites.

Frequent component failure can be correlated with poor road conditions and infrastructure reported by the majority of respondents in both countries, as well as bicycle designs poorly suited to harsher terrain, such as muddy roads during rainy season. Frequent component failure results in more frequent trips to repair shops and payment for replacement parts and services, exacerbating affordability barriers discussed previously. One Malawian bicycle user relates, “The worst thing about my bicycle is that it requires general service more frequently because the spare parts are not durable…in the past we could use a tire for three years, but the ones that are available on the market today last just for a year.” Around 80% of bicycle users use this method to repair their bicycles–only 20% fix by themselves. As mentioned, supply chain issues created by the pandemic require users to make do with inferior spare parts.

Another barrier related to quality is the desired ability to carry heavy, large loads on bicycles. In Ghana, 64% of these cases came from rural respondents. In Malawi, this issue is present in all site types, but is slightly more common in peri-urban sites likely because of the higher presence of bicycle taxis.

Another high-level barrier of interest is personal riding experience and context. In urban areas, bicycle riders have to deal with aggressive motor vehicle drivers and many lack knowledge of traffic cycling rules. In all three site types, respondents reported poor infrastructure and lack of organizational and policy support.

Enablers

As with the barriers, the enablers of adoption of bicycles were also grouped into families or parent codes. Personal attitudes and perceptions, personal riding experience, and affordability make up the primary enablers in both Ghana and Malawi. As discussed previously, personal attitudes and perceptions and affordability were among the primary barriers as well. This connection will be discussed further in this section of the report.

Personal attitudes and perceptions accounted for 703 of 1888 coded enablers, or 37.2%. Personal riding experience was the next most frequently coded enabler at 387 case count, so personal attitudes and perceptions is the outstanding enabler in these socio-economic contexts. Affordability follows closely at 301 case count, making this the number three enabler. As mentioned, affordability was the primary barrier to adoption of bicycles. As you can see, affordability was the most common theme mentioned across the board, which demonstrates the value that the communities place on this aspect of technology.

Above: A man carrying children on bicycle, in a village near Zomba, Malawi. Photo: MIT D-Lab/Megha Hegde

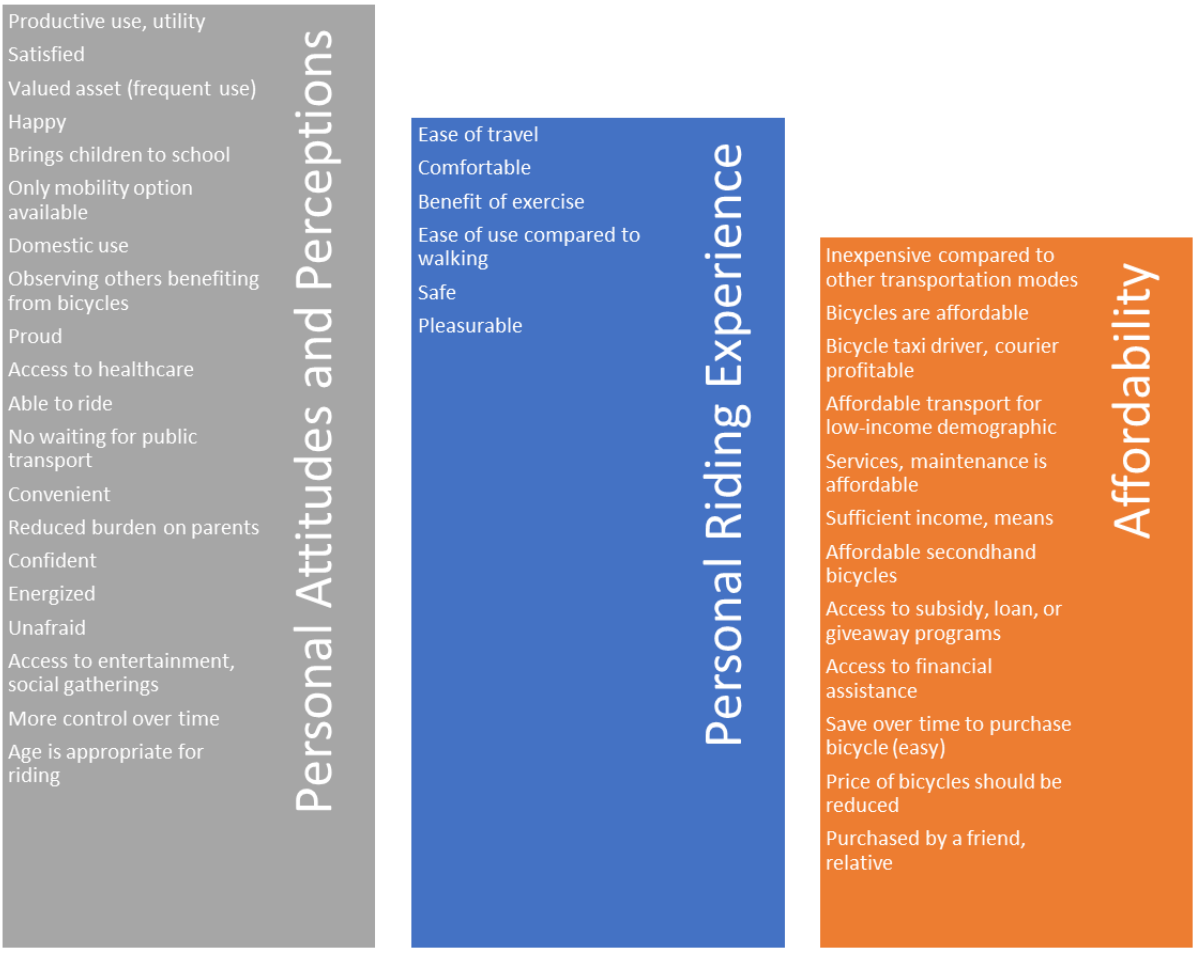


Figure 8: Top Enablers

Personal attitudes and perceptions coded as enablers include productive use and utility, which made up 32.3% of this code family, and satisfaction with their bicycle, at 20.1%. Respondents valuing bicycles for productive use makes up the primary enabler in this family, and was reported in all site types, but most frequently by peri-urban respondents likely living in poverty. A Ghanaian non-user describes the advantages experienced by people with access to a bicycle, saying, “I don’t have a farm but I work on peoples’ farms for income…The women who have the bicycle usually get to the farms earlier and they get to do more work. For those of us who do not have the bicycle, we do get there late and by that time much of the work has been done.” In Ghana, respondents in rural sites identified the bicycle as their only mobility option more frequently, but in Malawi, this came more often from urban and peri-urban respondents. As the non-user reported, bicycle use can have a significant impact on earned income in rural areas of Ghana, allowing users to commute to farms more easily.

Additional attitudes and perceptions mentioned by interviewees (<6%) include feelings of happiness, pride, confidence, increased energy, and being unafraid. Observing others benefiting from bicycles, not having to wait for public transportation, domestic use, ability to ride, and convenience also made up personal attitudes and perceptions that enable bicycle use. People living in poverty referred to their bicycle as a valuable asset that is frequently used twice as often than those likely not living in poverty.

Interviewees praised bicycles for their ease of travel–faster speed, reduced travel time and the ability to cover longer distance compared with walking. This made up 46.2% of personal riding experience enablers identified. Users in Ghana reported the significant difference in travel time compared with walking, saying "when I had the bike, I could go fast. Usually takes me about 15 to 30 minutes with the bike but since it is not there, it takes me about an hour," and "using a bicycle is about 25 minutes. If I am to walk I can't use 25 minutes. I will spend about two hours." Users also shared that bicycles were safer and more pleasurable than walking, leading to easier use. Urban and wealthier riders identified exercise and pleasure as enablers more than twice as often as other riders. The benefit of exercise was also more common in Ghana than in Malawi. Of the personal riding experience enabler code cases, comfort accounted for 21.3%. Rural riders identified comfort less than urban and peri-urban riders, and this had high co-occurrence with poor road conditions in rural respondents.

The main benefit of bicycles regarding affordability is that it is inexpensive compared to other transportation modes, which made up 36.8% of affordability enablers. This was especially true in Ghana; where bicycle affordability compared to other modes accounted for over 50% of enablers in this family. One Ghanian respondent explains, "I can't afford a motor at this level but I can afford bicycle at this level." Financial assistance, subsidies, and giveaways were more commonly mentioned by higher income Ghanaian urban and peri-urban residents, indicating a potential mismatch in this kind of assistance in these communities. In Malawi, income from bicycle taxi and courier services was a major enabler among low-income respondents, especially in peri-urban areas. Service and maintenance in addition to upfront bicycle affordability was important across all segments, especially rural. Affordability was mentioned as an enabler two times more in urban sites, whereas this was the greatest barrier for rural sites. Urban sites specifically identified bicycle cost, income, and savings over other transport as affordability enablers.

Summary of Phase I

Data collected during Phase I of the project allowed the team to identify important themes related to bicycles in these contexts. One of these themes is the importance of load-carrying to bicycle-use purposes, often for productive use such as transportation to farm and bicycle taxi business. Another important theme is shared ownership and usage of bicycles. Affordability represents the primary set of barriers to bicycle use, followed by perceptions and attitudes and frequent component failure. Perceptions and attitudes and affordability also make up important enablers to bicycle use; the bicycle is more affordable compared to motorized vehicles and

public transportation. Personal riding experience also contributes to the enabling environment of bicycle use. Bicycle use is an important mode of transport, and findings from this phase further validate the efforts of research into barriers and enablers of bicycles in sub-Saharan Africa.

3.3. Findings from Phase II

In Phase II, the team sought to identify intra household dynamics as they relate to bicycle use, gather data over a longer period of time on the challenges people face when riding bicycles and bicycle use, as well as identify design challenges and opportunities. In the final sample, the team included 24 households in Malawi and 24 households in Ghana for a total of 48 households.

3.3.1. Sample and demographics

For the pre-screen survey, 84 respondents in Ghana and 54 respondents in Malawi completed the survey. From those pre-screen respondent populations, and based on the inclusion criteria for Phase II, 24 households—12 in each of two study sites per country—were selected for each country for inclusion in the full Phase II study. In Figure 9 and Figure 10 below, the breakdown of the respondents by sex, age, and Poverty Probability Index (PPI) is shown.[1] In general, the Ghana sample tended to be more skewed toward men and higher wealth: in part, an indication of the country's stronger economic position relative to Malawi.

In Malawi, 37% (8) of down-selected respondents were female. In Ghana, it proved more difficult to find female bicycle rider respondents who fit all of our other inclusion criteria. Hence, they comprise only 8% (2) of the down-selected respondents.

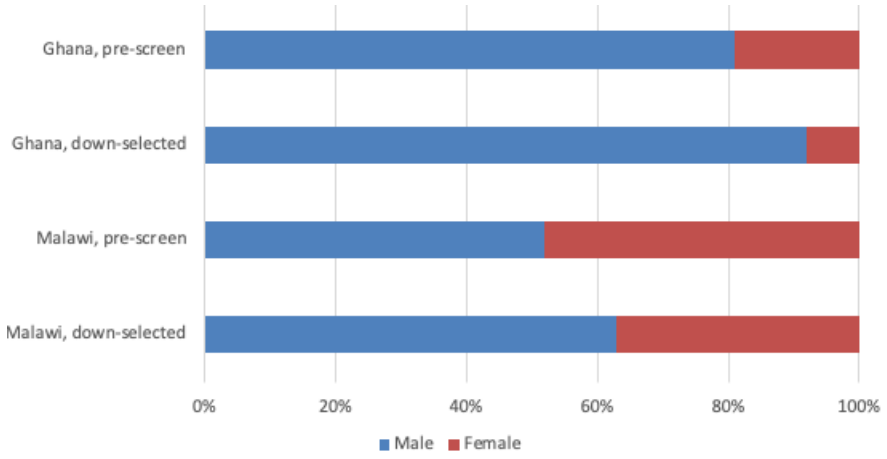


Figure 9: Sex by country for pre-screen and final

[1] PPI is a rigorous, standardized measure of household wealth based on asset ownership that is compared against a base poverty line to determine whether a household is likely living in poverty or not

The age breakdown of the down-selected populations is quite similar across both countries. The largest age cohort were adults aged 25-39, or approximately 40% of the down-selected respondents in both countries. Young adults comprised approximately 20% of down-selected respondents, older adults 25%, and elderly adults 15%.

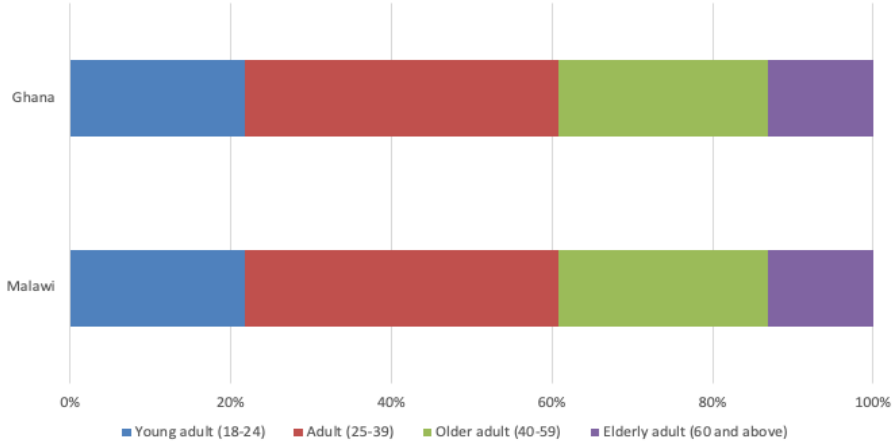


Figure 10: Age breakdown for Ghana and Malawi, down-selected

In terms of PPI as shown in Figure 11, 75% of households across both countries—88% in Malawi and 61% in Ghana—were considered likely to be living in poverty against a $3.20/day baseline.[2] The higher likelihood of poverty in the Malawi sample speaks to the relatively weaker economic position of Malawi relative to Ghana.

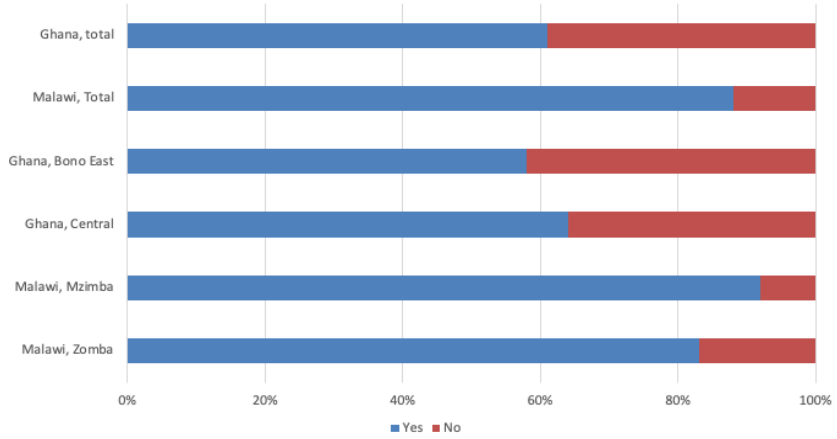


Figure 11: Likely living in poverty, $3.20/day, by country and region, down-selected

[2] In calculating the Ghana PPI, we elected to not include one question (regarding the region where the household resides). When included, this question ensured that virtually everyone in the sample was likely not living in poverty, which seemed odd, given that most households have little agency over their geographical location. Because this had no reflection on actual asset ownership of a household, we felt this was an acceptable course of action.

3.3.2. Transportation practices

In both Malawi and Ghana, all households who were participants in the study used a bicycle, making it the most common form of current transportation (Figure 12). Walking was the second-most common transportation practice, owing in large part to its affordability. More expensive, motorized transportation options tended to be used less frequently and for specific purposes that required either time sensitivity (e.g., health-related activities) or traversing long distances (e.g., visiting family, going to market, business-related commutes).

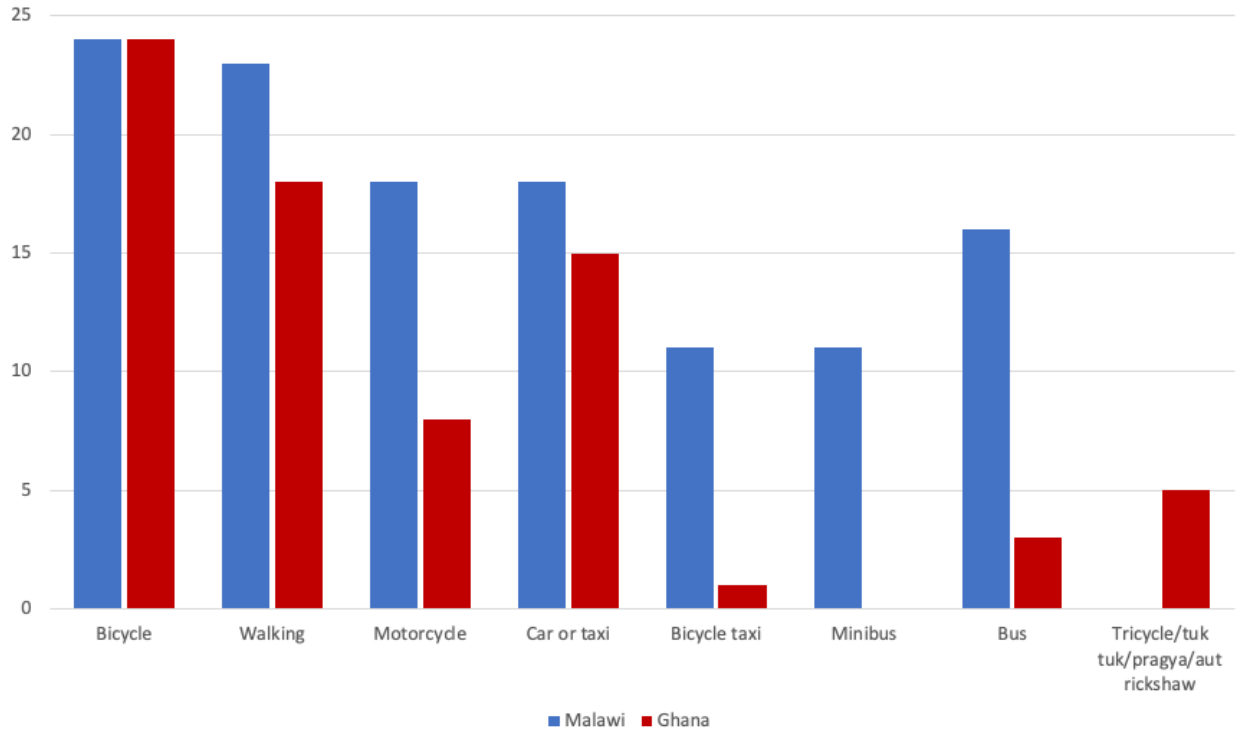


Figure 12: Transportation modes for Ghana and Malawi (choice counts)

3.3.3. Bicycle use and purpose

Unsurprisingly, most household members know how to ride a bicycle and use it frequently. Indeed, finding non-users in every household proved difficult during the pre-screen survey, especially in Malawi. Bicycles, in addition to being the most common form of transportation, were also the most frequent form of transportation: most households reported daily use (Figure 13). With the exception of going to school, the purpose of bicycle uses among adults and children tended to be similar: going to market or the farm, running errands, load-carrying (especially farm-related), and visiting friends and family (Figure 14). In Malawi, bicycles were also used frequently for health-related activities, such as going to the hospital.

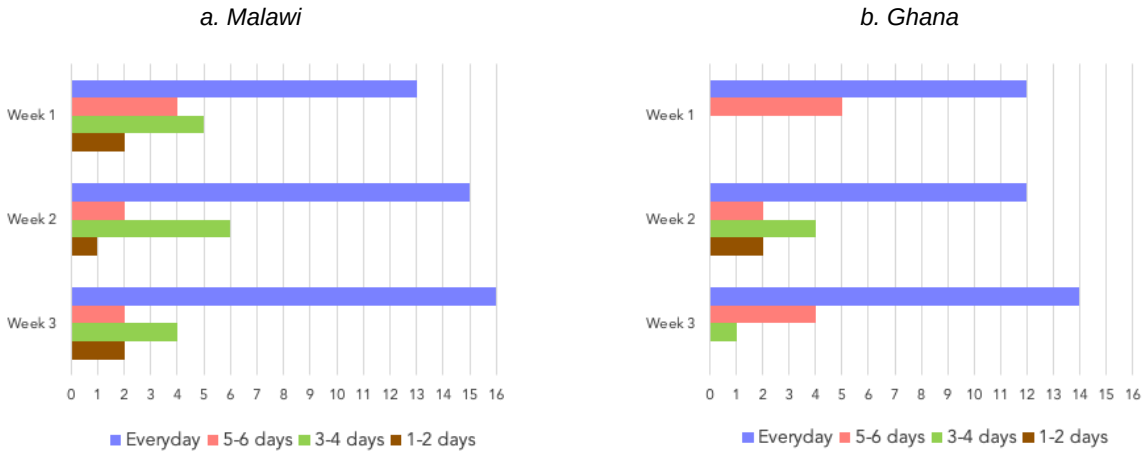


Figure 13: Frequency of bicycle use per week for Malawi and Ghana (choice counts)

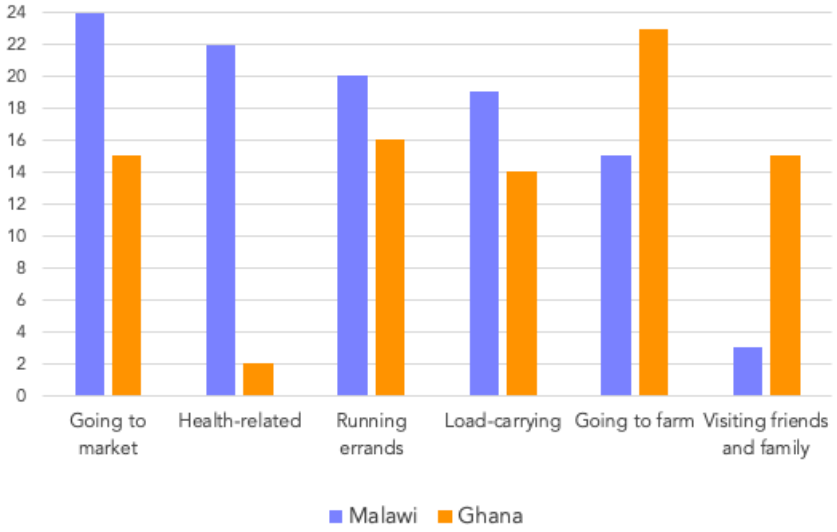
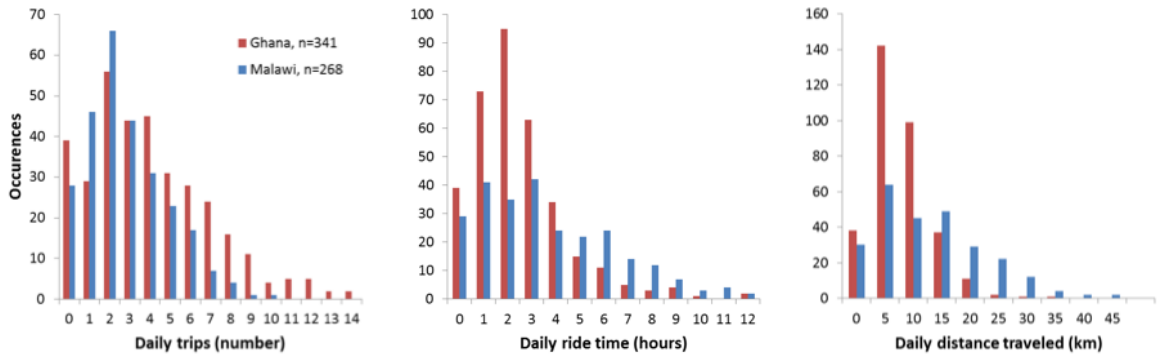


Figure 14: Bicycle use and purpose for Ghana and Malawi (choice counts)

While use tended to be quite frequent, the nature of bicycle use proved irregular, as can be seen from the sensor data: large variations in the number, duration, and distance of trips were measured (Figure 15).



a. Trips per day (number) *b. Daily use duration (hours)* *c. Daily use distance (km)*

Figure 15: Distributions of daily bicycle trip number (a), duration (b), and distance (c) for bicycles instrumented with tracking sensors in Ghana

Similar to the full study sample, individual rides were relatively irregular.

Figure 16 presents an illustrative example of individual usage behavior for a bicycle in Malawi. For this rider daily trips range from zero to six, and distance from zero to more than 25 km per day (

Figure 16, left). The daily number of trips correlates well with the daily distance traveled (

Figure 16, right).

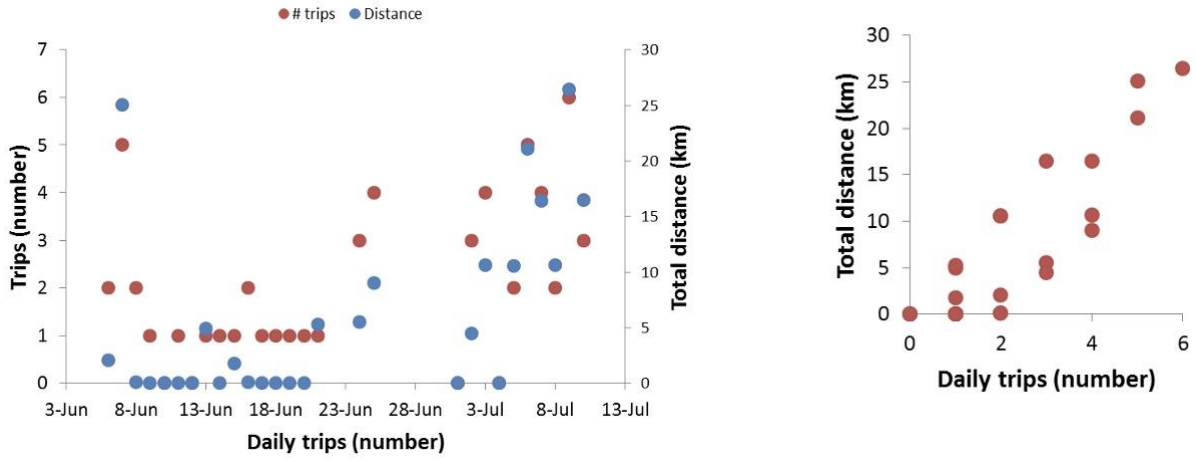


Figure 16: Bicycle usage tracking data for an individual rider in Malawi

Bicycle usage measured by the tracking sensors is also compared to the demographics of the primary rider in each household. Bicycle usage in each of the study sites in Malawi completed similar numbers of trips. However, bicycles in the Zomba area of southern Malawi were in use for more hours each day on average when compared with the Mzimba area of northern Malawi (Figure 17). In Ghana, riders in the northern study site (Anyima) completed more trips and over longer distances each day on average compared with riders in the southern study site (Ebukrom) (Figure 19). With regard to gender, distinct differences in usage behavior were measured during the one month of bicycle sensor tracking. Across all study sites, female riders completed fewer trips over shorter distances and durations when compared to male riders, especially in Mzimba, Malawi. With regard to age, riders above and below the median in Malawi completed similar numbers of trips. However, riders over 40 years old rode over longer distances each day when compared to riders under 40. In Ghana, primary riders older than the median age of the study participants (48.5 years old) completed more trips over longer distances and durations each day on average when compared to primary riders younger than the median.

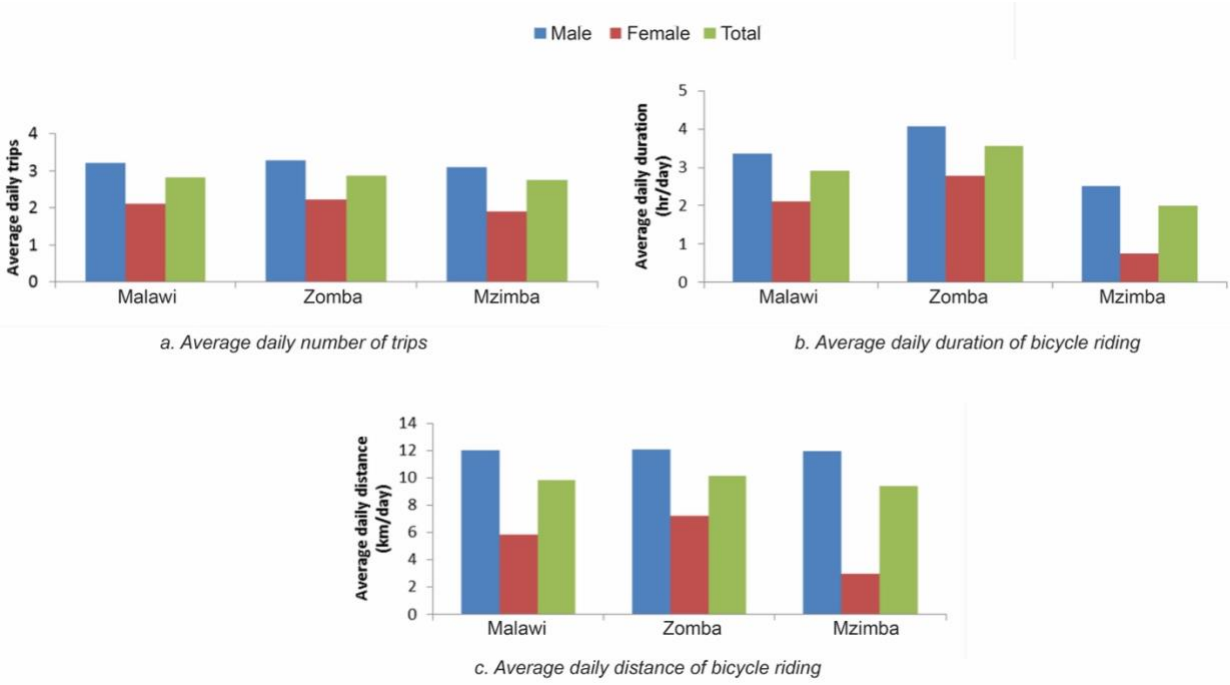
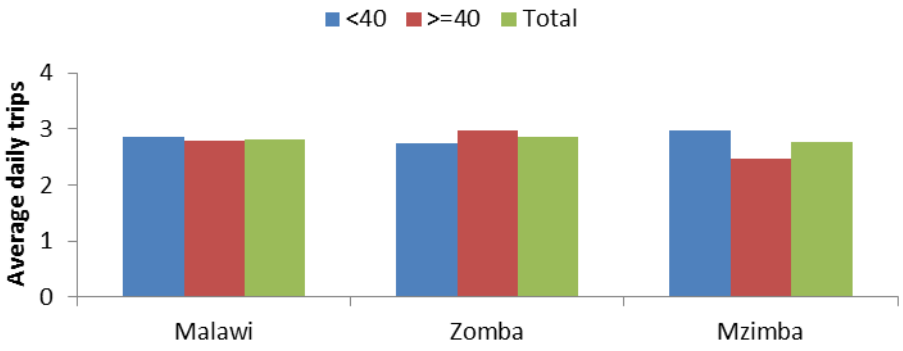
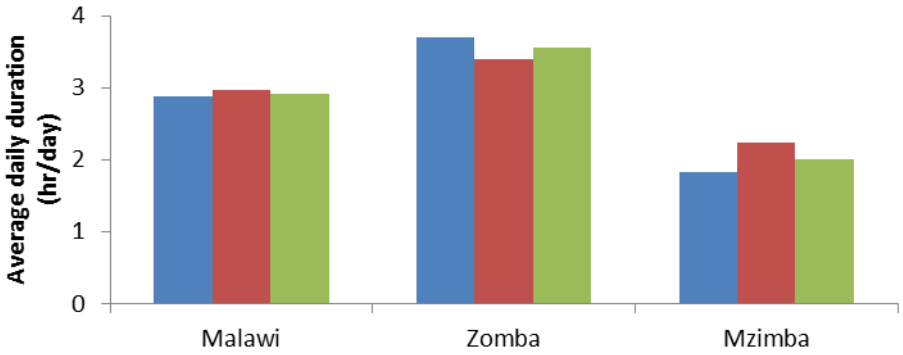


Figure 17: Bicycle tracking sensor data for primary riders in Malawi and two Malawian research sites segregated by gender[3]

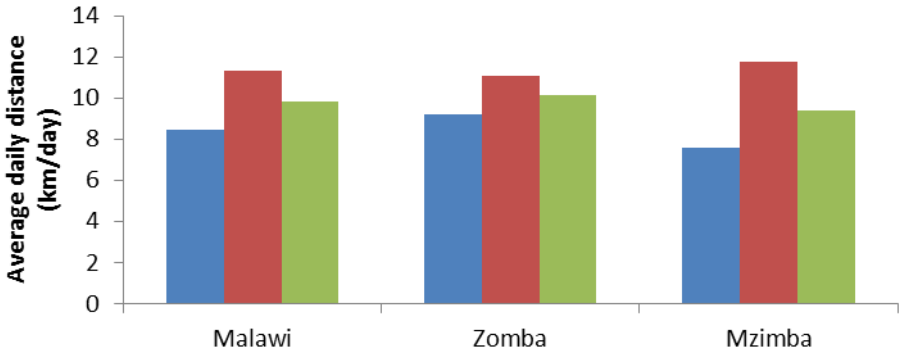
[3] Gender data for Ghana not included, as the Ghana sensor data only included one female.



a. Average daily number of trips

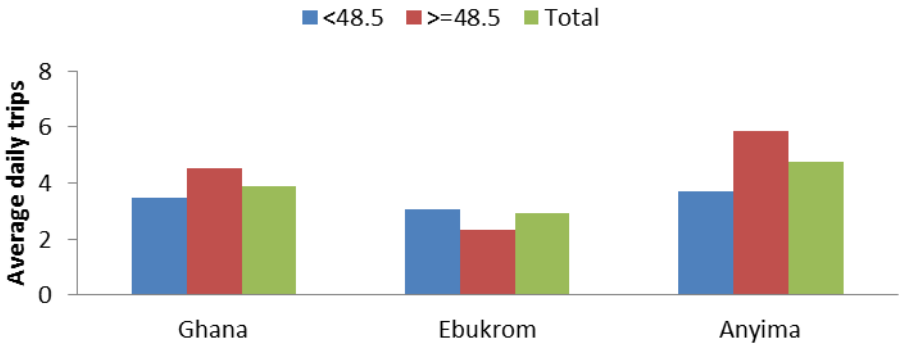


b. Average daily duration of bicycle riding

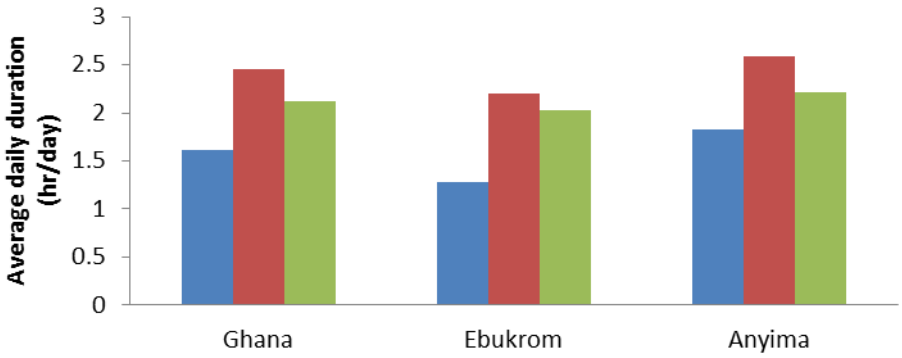


c. Average daily distance of bicycle riding

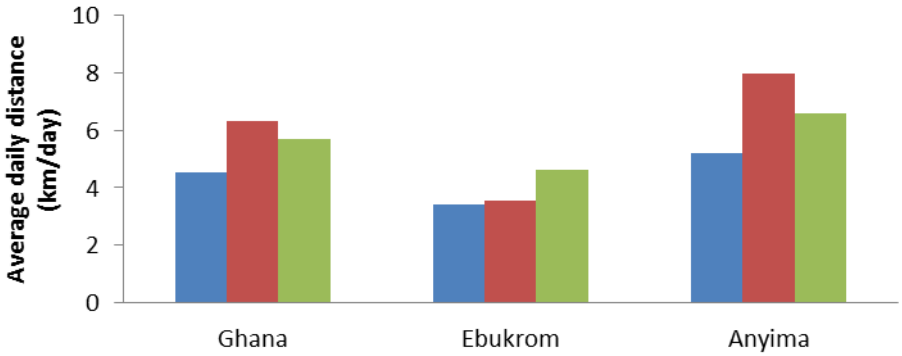
Figure 18: Bicycle tracking sensor data for primary riders in Malawi and two Malawian research sites segregated by above and below the median age (40 years for all riders)



a. Average daily number of trips



b. Average daily duration of bicycle riding



c. Average daily distance of bicycle riding

Figure 19: Bicycle tracking sensor data for primary riders in Ghana and two Ghanaian research sites segregated by above and below the median age (48.5 years for all riders)

The tracking sensor data can also be segregated by bicycle type as determined from interview and photo data (Figure 20 and Figure 21). Interview and photo data from the user exit interviews were used to determine the type (e.g. Buffalo, ladies, mountain, roadster), condition of, and important features (e.g. carrier) of each bicycle. Across both study sites in Malawi, the double

roadster (roadster bicycle with two top tubes and reinforced fork and carrier) and Buffalo bicycles were used over longer distances each day on average compared to other bicycle types. This is consistent with interview responses from primary riders which indicated the importance of load carrying, which both the Buffalo and double roadster are well suited for. Mountain bikes are technically more complicated than other bicycle types (multiple speeds and derailleurs), which could account for their relatively low level of usage compared to other bicycle types. Bicycles that were monitored in Ghana and identified from interview responses and photos did not exhibit large differences in usage based on bicycle type (Figure 21). It should be noted that several bicycle types could not be identified due to lack of data, and the average across all bicycle types ("Average all") represents tracking sensor data from the full Ghana sample, not only the identified bicycle types.

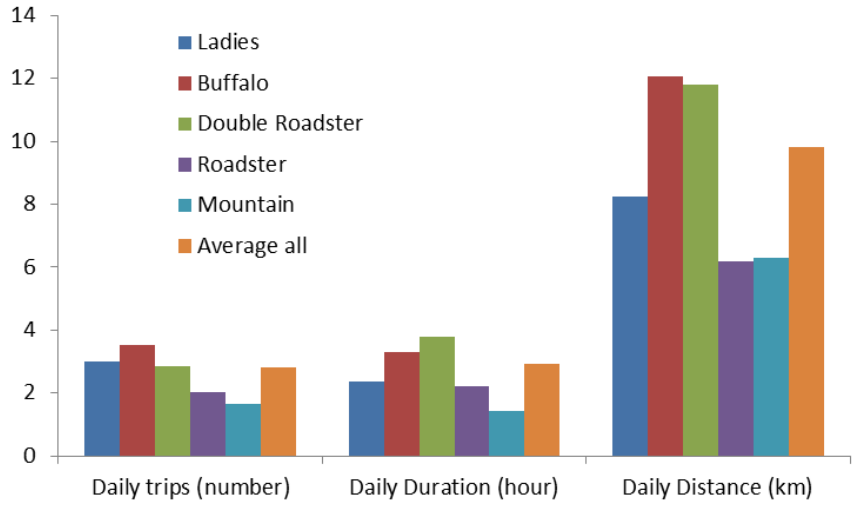


Figure 20: Bicycle tracking sensor data for primary riders in Malawi segregated by bicycle type

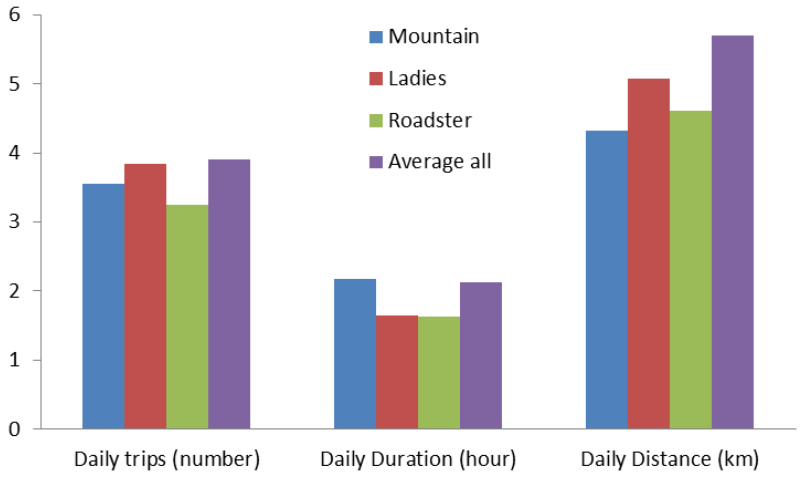


Figure 21: Bicycle tracking sensor data for primary riders in Ghana segregated by bicycle type

The decision to make the unit of analysis the household proved important in illuminating intra-familial dynamics regarding bicycle use. The bicycle was often usually linked to a primary user, who was most likely also the head of the household (75% of households in our sample). The exception to this trend was in the instances where the bicycle was procured for the specific purpose of improving children's access to school, which was the case in 13% (3) of households in Malawi. Few respondents noted that the bicycle was used according to the most important or immediate need. Indeed, the most important need was often equated with, and decided by, the needs of the primary user. Because the head of the household tended to be male, the intra-familial power dynamics at play in bicycle use and access also have important gender implications, often leaving women with fewer transportation options that could restrict their mobility, increase transit time (walking), or increase transit costs (motorized vehicles). This helps illuminate the notion that access does not necessarily equal use, and further speaks to the importance of viewing household bicycle access and use not as a binary (access or no access) but rather as a spectrum (varying degrees of access even when a household has a bicycle).

3.3.4. Ownership

Bicycles tended to be purchased from retail shops within the last 5 years, as seen in Table 4. In Ghana, most bicycles were second-hand purchases while in Malawi, nearly 9 in 10 households purchased their bicycle new. This surprising finding in Malawi, which differs from our findings in Phase I, is perhaps explained by the higher rate of purchase from a bicycle organization or NGO (38%). This also indicates that organizations promoting bicycles likely play a significant role in improving bicycle access in rural communities.

Purchased:	*Ghana*	*Malawi*
A new bicycle	38%	88%
At a retail shop	88%	54%
From bicycle organization/NGO	4%	38%
Within last 5 years	92%	58%

Table 4. Bicycle purchase details

Ownership was also linked to household dynamics. Generally, the trend seemed to be that the head of the household, often male, was also the purchaser (96% and 63% of purchasers in Ghana

and Malawi were male, respectively). The purchaser tended to also be the owner, primary user, and responsible for ongoing maintenance costs. In addition, most households had only one bicycle: in Malawi, there were 36 bicycles across 24 households; in Ghana, 28 bicycles across 24 households. This had the effect of exacerbating access issues within the family when multiple tasks that required the bicycle needed to be accomplished simultaneously.

3.3.5. Design considerations and requirements

Overall, most respondents were satisfied with most aspects of the bicycle design, including weight, height, and comfort (with and without loads). However, room for improvement exists. In Malawi, 9 respondents (38%) said their bicycle was too heavy while 8 respondents (33%) in Ghana said their bicycle was too light. In Ghana, 6 respondents (25%) noted that the seats were uncomfortable.

Load carrying was a popular use for a bicycle: 87% of respondents in Ghana and 96% in Malawi. Notably, comfort levels decreased when carrying a load: in Malawi, 10 respondents (42%) said it was uncomfortable while carrying a load; in Ghana, it was 8 respondents (35%).

Few modifications were made (see Figure 22 for some examples). In Malawi, 3 households made modifications: to add a basket for load carrying and to change gears. In Ghana, 8 households made modifications to their bicycles: 7 added a carrier/basket and 1 added a mudguard and bell; 6 of these modifications were done at repair shops, and respondents were satisfied with the end results.

Figure 22: Bicycle from Ghana and Malawi; Sources: University of Malawi, University of Cape Coast

Somewhat surprisingly, little evidence of a gendered pattern in design satisfaction was found. Several reasons may explain this: women may have become accustomed to riding bicycles that may not be appropriate or ideal in terms of fit, it may speak to desirability bias in responses, or it may be due to the relatively small size of our sample.

3.3.6. Barriers and enablers to adoption and use

Barriers to adoption and use were considerable (see Figure 23). Affordability is a key challenge: about two-thirds of households across both countries (67% in Malawi, 64% in Ghana) thought the bicycle purchase was unaffordable. Several households reported having to save funds in order to purchase a bicycle. In terms of access, 62% of people who did not have access to a bicycle when they needed it was because someone else was using it in the household (or less often, a friend).

Gender and age were found to play a role in bicycle use. Bicycle non-users (and/or limited users, in the case of Malawi) in our sample tended to be women (82% in Malawi, 87% in Ghana) as well as young children and the elderly. In Malawi, the main reason non-users reported not using a bicycle was because they did not know how (6 respondents, all women). In Ghana, 11 non-users had never used a bicycle (almost all women) before while 11 had used a bicycle before.

Most respondents in Malawi (92%) and a majority in Ghana (61%) reported facing a major challenge with their bicycle in the last month. Maintenance and repair issues, (including part and component failure), was the most cited challenge, especially in Malawi (Figure 20)—a result consistent with findings from Phase I. Failed components in Malawi consisted of tires (54% of households) and tubes (42%), and in Ghana tubes (22%) and chains (17%). Approximately 50% of households in both countries experienced barriers related to health and safety (primarily exhaustion), and climate and infrastructure (primarily unfavorable road conditions).

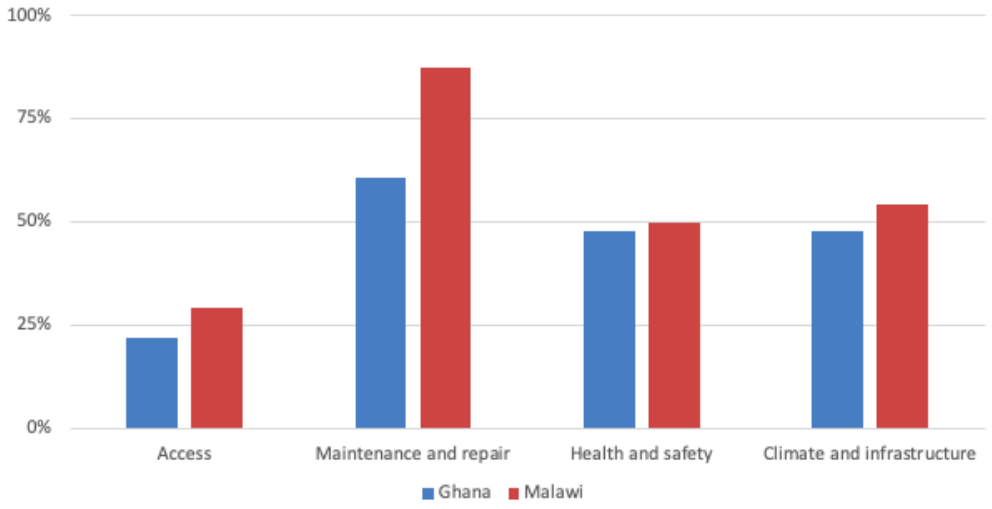


Figure 23: Barriers for Ghana and Malawi (percent of households)

While several barriers to adoption and use existed, the bicycle was still considered a valued household asset. Despite complaints about the upfront purchase cost, bicycles were nonetheless viewed as affordable relative to other transportation options (Figure 24).The ease of use, convenience, and speed/time savings they afforded were chief reasons households continued to consistently use bicycles, despite the several challenges and barriers.

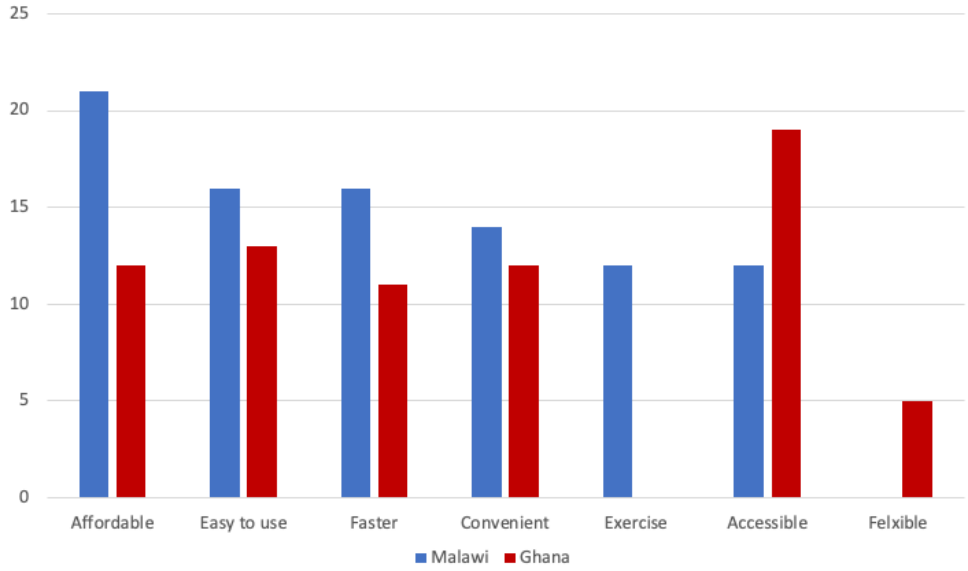


Figure 24: Top enablers for Ghana and Malawi (choice counts)

4. CONCLUSION

This section outlines some of the key conclusions from Phase II, recommendations, and who can address the recommendation. These findings build on the work completed in the scoping study and Phase I.

Conclusion	Recommendation	Who can act?
Intrahousehold dynamics matter when it comes to bicycle use. Male heads of household are often the owners of bicycles and their needs (as they relate to bicycle use) are often met first before others in the household. The use of the bicycle is often tied to the user rather than the task. The transportation needs of the household are often not met by one bicycle.	-Programs that provide greater access to bicycles for women and children could be beneficial, while also providing access to bicycles for male users. -Consider introducing aspects of the bicycles that are more attractive for female users and less attractive for make users. -Teaching women and children how to ride a bicycle will also be important.	-Implementing partners -Government programs for bicycles

Most people said that the bicycle is unaffordable.	-Design a bicycle that is more affordable and durable. -Create financing options that are more affordable for bicycle purchase. Could include things like rent to own, payment in installments, and leasing for a short period of time.	-Universities and/or manufacturers who can work on the design of more affordable and durable bicycle -Financial institutions or implementing partners providing access to bicycles
Broken parts remain the primary challenge in both countries. Broken parts occur often and are often unaffordable.	-Provide access to affordable, durable parts. -Consider sourcing more durable parts from places like India while considering the high import duties for bicycle parts. -Design new parts that are more durable and affordable. -Train small local businesses or users in how to repair their bicycles, so that it is more affordable to repair bicycles.	-Implementing partners -Bicycle mechanics -Universities, civil society or non-government organizations, and/or manufacturers who can work on the design of more affordable and durable parts
Modifications were not as common as expected, but of the modifications people had made or would like to make, adding a load carrying option would be best. However, this modification is often not affordable. In addition, some people said that their bicycles were too light to carry a load.	-Add gears or change existing sprockets on bicycles to make it easier to carry a load. -Design load carrying modification that is affordable, such as a low cost carrier made from locally available materials -Consider developing a heavier bicycle that is better suited for load carrying.	-Manufacturers
The study did not reveal major design preferences based on gender. Bicycles are used by many different people in the household	-Develop a bicycle that can easily be adjusted to address different size riders.	-Implementing partners -Universities and/or manufacturers who can work on the design of more affordable and durable parts

Table 5: Conclusions and next steps

4.1. Next steps and future work

Next steps

This study has revealed a number of interesting findings related to bicycle use, ownership, design constraints, and barriers to and enablers of bicycle use. In terms of next steps, we will share the results with key collaborators and discuss ways in which the research applies to their work.

Future work

There is also still work to be done as outlined in the recommendations section such as developing bicycle programs that target women and children, design improvements for bicycle parts and load carrying options, and adapting financing mechanisms to make bicycles more affordable, among others. In addition, there could also be opportunities to explore these issues from Phase II in more urban or peri-urban areas. Finally, there could be additional work related to using sensors to study things like health benefits and looking at options to measure bicycle use for carbon financing. There are also opportunities to improve sensor solutions for tracking bicycles.

The photo above was taken in Zomba when Megha Hegde, a D-Lab researcher traveled to Malawi to oversee the beginning of data collection for Phase II. Left to right: Sly Munthali (University of Malawi), Megha Hegde, Chinsisi Kanyerere (World Bicycle Relief, Malawi), Spy Munthali (University of Malawi), Esther Njiwa (University of Malawi), and two local community members. Photo: MIT D-Lab/Megha Hegde

5. REFERENCES

1. Acheampong, R. A., & Siiba, A. (2018). Examining the determinants of utility bicycling using a socio- ecological framework: An exploratory study of the Tamale Metropolis in Northern Ghana. *Journal of Transport Geography*, *69*(April), 1–10. https://doi.org/10.1016/j.jtrangeo.2018.04.004
2. Adom-Asamoah, G., Amoako, C., & Adarkwa, K. K. (2020). Gender disparities in rural accessibility and mobility in Ghana. *Case Studies on Transport Policy*, *8*(1), 49–58. https://doi.org/10.1016/j.cstp.2019.12.006
3. Amoako-Sakyi, R., & Owusu, S. A. (2012). BICYCLES : AN ANSWER TO MOBILITY NEEDS OF RURAL Authors. *2nd African Community Access Programme (AFCAP) Practitioners Conference*, 1–11. https://doi.org/10.13140/2.1.3676.3525
4. Amos, P. (2008). *Safe, Clean, and Affordable. Transport for Development. The World Bank Group's Transport Business Strategy 2008-2012.* The World Bank.
5. Appropriate Technology. (2017). Village bicycle project transforms lives. *Appropriate Technology, 44(1)*, 60–61.
6. Ardizzi, M. (2018). *Bicycles for development in Uganda : a study of perceptions, organizations and globalization* [The University of British Columbia]. https://doi.org/10.14288/1.0375880
7. Baker, L. (2018). *Scripting Mobilities in sub-Saharan Africa: a Case Study of Second-Hand Bicycle Networks* [Cardiff University]. http://orca.cf.ac.uk/114557/
8. Baker, L. (2019). Scripting the mobile development subject: a case study of shipping second-hand bicycles to Africa. *Social & Cultural Geography*, 1–19. https://doi.org/10.1080/14649365.2019.1652930
9. Baker, L. (2020). Constructing sub-Saharan African mobilities through the flow of second-hand objects: Scripting bicycles for Namibian users. *Journal of Transport Geography*, *83*(January), 102656. https://doi.org/10.1016/j.jtrangeo.2020.102656
10. Bryceson, D. F., Mbara, T. C., & Maunder, D. (2003). Livelihoods, daily mobility and poverty in sub- saharan Africa. *Transport Reviews*, *23*(2), 177–196. https://doi.org/10.1080/01441640309891
11. Calvo, C. M. (1994). Case Study on Intermediate Means of Transport Bicycles and Rural Women in Uganda. In *Sub–Saharan Africa Transport Policy Program* (No. 12). https://www.ssatp.org/publication/case-study-intermediate-means-transport-bicycles-and-rural- women-uganda-part-three
12. The Economist. (2008). On your bicycle. *Economist*, 389 p. 61. *The Economist Historical Archive*, http://tinyurl.gale.com/tinyurl/CMq3A8 Accessed 27 Nov. 2019.

13. England, A., & Manson, K. (n.d.). *Steering a path to making bicycles in Africa | Financial Times*. Retrieved September 10, 2020, from https://www.ft.com/content/3520c62e-e9bc-11e0-bb3e- 00144feab49a

14. Fiala, N., Garcia-Hernandez, A., Narula, K., & Prakash, N. (2019). *Wheels of Change: The Impact of Bicycle Access on Girls' Education and Empowerment Outcomes in Rural Zambia*. Innovations for Poverty Action (IPA). https://www.poverty-action.org/study/wheels-change-impact-bicycle-access- girls'-education-and-empowerment-outcomes-rural-zambia

15. Gauthier, A., & Hook, W. (2005). Tapping the Market for Quality Bicycles in Africa. *Sustainable Transport*, 8–12. https://www.itdp.org/publication/seoul-and-sustainable-transport-leading-by- example-issue-17-2005/

16. Girls Not Brides, & Janaki Women Awareness Society. (2017). *Keeping girls in secondary school with bicycles* (Issue April). https://www.girlsnotbrides.org/resource-centre/keeping-girls-secondary- school-bicycles/

17. Hamilton, R. (2012). *Can the Buffalo change Africa's bicycle culture? - BBC News*. Can the Buffalo Change Africa's Bicycle Culture? Retrieved September 10, 2020, from http://www.bbc.com/news/world-africa-17115923

18. Hine, J., & Rutter, J. (2000). Roads, Personal Mobility, and Poverty: The Challenge. *Transport and Poverty Alleviation Workshop*, 1–12. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.523.8897

19. International Bicycle Fund. (2003). *Bicycle Statistics: Usage, Production, Sales, Import, Export*. Retrieved September 2, 2020, from http://www.ibicycle.org/library/statistics-data.htm

20. Mahapa, S. (2003). *Integrating Gender Into World Bank Financed Transport Programs-Case Study South Africa*.

21. McSweeney, M., Millington, B., Hayhurst, L., Wilson, B., Ardizzi, M., & Otte, J. (2020). 'The bicycle breaks down. What are they going to do?' Actor-networks and the Bicycles for Development movement. *International Review for the Sociology of Sport*. https://doi.org/10.1177/1012690220904921

22. Muralidharan, K., & Prakash, N. (2017). Cycling to School: Increasing Secondary School Enrollment for Girls in India. *American Economic Journal: Applied Economics*, *9*(3), 321–350. https://doi.org/10.1257/app.20160004

23. Nkurunziza, A., Zuidgeest, M., Brussel, M., & van Maarseveen, M. F. A. M. (2012). Exploring factors affecting the potential of bicycle commuting in Dar-es-Salaam. *Conference CODATU XV: The Role of Urban Mobility in (Re)Shaping Cities*.

24. Peier, J. (2015). *Access to transport for the base of the pyramid: Measuring the Impact of Bicycles in Burkina Faso* [University of St. Gallen]. https://www.poverty.ch/wp-content/uploads/2017/10/VeloBurkinaPeier.pdf

25. Pojani, D., & Stead, D. (2015). Sustainable urban transport in the developing world: Beyond megacities. *Sustainability (Switzerland)*, *7*(6), 7784–7805. https://doi.org/10.3390/su7067784

26. Porter, G. (2014). Transport Services and Their Impact on Poverty and Growth in Rural Sub-Saharan Africa: A Review of Recent Research and Future Research Needs. *Transport Reviews*, *34*(1), 25–45. https://doi.org/10.1080/01441647.2013.865148

27. Räber, N. (2014). *Access to transport for the base of the pyramid: Measuring the impact of bicycles in Tanzania*. https://velafrica.ch/media/archive1/PDF_Deutsch/Wirkungsstudie/Measuring_the_impact_of_bicycl es.pdf

28. Savage, S. (2020, July 25). "I can pedal faster than a man can run" - how bicycles are changing the dynamic on Africa's roads. *The Guardian*, 1–8. https://www.theguardian.com/global- development/2017/jul/25/i-can-pedal-faster-than-a-man-can-run-how-bicycles-are-changing-the- dynamic-on-africas-roads

29. Shirazi, Q. (2020, July 8). Business of knife sharpeners booms. *The Express Tribune*. https://tribune.com.pk/story/2253857/business-of-knife-sharpeners-booms

30. Sieber, N. (1999). Transporting the yield: Appropriate transport for agricultural production and marketing in Sub-Saharan Africa. *Transport Reviews*, *19*(3), 205–220. https://doi.org/10.1080/014416499295493

31. Sietchiping, R., Permezel, M. J., & Ngomsi, C. (2012). Transport and mobility in sub-Saharan African cities: An overview of practices, lessons and options for improvements. *Cities*, *29*(3), 183–189. https://doi.org/10.1016/j.cities.2011.11.005

32. Song, L. K. (2003). The Potential of Bicycles As a Means of Transport for Learners in Rural South Africa. *Proceedings of the 22nd Southern African Transport Conference (SATC2003)*. https://repository.up.ac.za/bitstream/handle/2263/6831/LieuwKieSong_Potential%282003%29.pdf?s equence=1

33. Song, L., Kirschen, M., & Taylor, J. (2019). Women on wheels: Gender and cycling in Solo, Indonesia. *Singapore Journal of Tropical Geography*, *40*(1), 140–157. https://doi.org/10.1111/sjtg.12257Ukoba, O. K., Ogunkoya, A. K., & Soboyejo, W. (2011). Development of an Eco-Friendly Bamboo Bicycle. *The Pacific Journal of Science and Technology, 12(1)*, 102–108. http://www.akamaiuniversity.us/PJST12_1_102 United Nations. (2019). *United Nations Commodity Trade Statistics Database*. comtrade.un.org

34. United Nations. (2019). United Nations Commodity Trade Statistics Database. comtrade.un.org

35. White, P. S., & Budnick, N. (2001). A New Bicycle for Africa. *Sustainable Transport, 12,* 26–29. https://www.itdp.org/publication/cuenca-gets-on-the-bus-issue-12-2001/

36. Wilson, S. S. (1973). Bicycle Technology. *Scientific American*, *228*(3), 81–91. https://www.jstor.org/stable/10.2307/24923004

37. World Bicycle Relief. (2019a). *2019 Impact Report*. https://worldbicyclerelief.org/wp-content/uploads/2020/05/WBR_2019-Impact-Report-3.pdf

38. World Bicycle Relief. (2019b). *2019 Kenya Impact Report*. https://worldbicyclerelief.org/wp- content/uploads/2020/05/2019-Kenya-Impact-Report_FINAL-051320.pdf

39. World Bicycle Relief. (2019c). Malawi Impact Report.